North Carolina Blue Crab (*Callinectes sapidus*) Fishery Management Plan Amendment 3

By

North Carolina Division of Marine Fisheries

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LIST OF ACRONYMS

ASMFC – Atlantic State Marine Fisheries Commission
CFVR – Commercial Fishing Vessel Registration
CHPP – Coastal Habitat Protection Plan
CRC – Coastal Resources Commission
CRFL – Coastal Recreational Fishing License
CW – Carapace Width
DAPD – Department of Agriculture, Pesticide Division
DCM – Division of Coastal Management
DO – Dissolved oxygen
EDC – Endocrine disrupting chemical
EEZ – Exclusive Economic Zone
EFH-HAPC – Essential Fish Habitat – Habitat Areas of Particular Concern
EMC – Environmental Management Commission
ESA – Endangered Species Act
FMP – Fishery Management Plan
FRA – Fisheries Reform Act
ITP – Incidental Take Permits
MMPA – Marine Mammal Protection Act
NCDEQ – North Carolina Department of Environmental Quality
NCDMF – North Carolina Division of Marine Fisheries
NCMFC –North Carolina Marine Fisheries Commission
NCWRC – North Carolina Wildlife Resources Commission
NOAA – National Oceanographic and Atmospheric Administration
RSCFL – Retired Standard Commercial Fishing License
RCGL – Recreational Commercial Gear License
SAFMC – South Atlantic Fishery Management Council
SAV – Submerged aquatic vegetation
SCFL – Standard Commercial Fishing License
SEAMAP – Southeast Area Monitoring and Assessment Program
SHA – Strategic Habitat Area
USACE – United States Army Corps of Engineers

EXECUTIVE SUMMARY

North Carolina's blue crab resource has been harvested since the 1800s and supports the state's largest and most valuable commercial fishery. The blue crab fishery in North Carolina is the fourth largest blue crab fishery in the United States. Blue crab is also targeted by recreational fishermen and is an important species in the coastal ecosystem serving as prey for many recreationally and commercially important species.

BLUE CRABS IN A BASKET.
Photo By: Corrin Flora

The 2018 stock assessment determined the North Carolina blue crab stock is overfished and overfishing is occurring. State law requires management action to be taken to end overfishing within 2 years and to recover the stock from an overfished condition within 10 years with a 50% probability of success from the date of adoption of the plan. A minimum harvest reduction of 2.2% in numbers of crabs from 2016 commercial hard crab landings is necessary to meet these statutory requirements.

The goal of the North Carolina Blue Crab Fishery Management Plan (FMP) is to manage the blue crab fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. Objectives for the FMP are: implement management strategies that maintain/restore the blue crab spawning stock with multiple cohorts and adequate abundance to prevent recruitment overfishing; restore, enhance, and protect habitat and environmental quality necessary to maintain or increase growth, survival, and reproduction of the blue crab population; use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the blue crab fishery and its ecosystem impacts; promote stewardship of the resource through increased public awareness regarding the status and management of the blue crab fishery, including practices that minimize bycatch and discard mortality.

COMMERCIAL FISHERMAN DEPLOYING A CRAB POT.
Photo By: Jessica Lee

To meet statutory requirements to achieve a self-sustaining population, sustainable harvest was addressed in the FMP. Other issues addressed in the plan encompassed the following general categories: non-quantifiable management measures, water quality, crab spawning sanctuaries, use criteria for terrapin excluder devices, and bottom disturbing gear. Specific recommendations for each issue are as follows:

1) Achieving sustainable harvest: To recover the North Carolina blue crab stock the selected management strategy is: a closed season where the region will remain closed for the entirety (Jan. 1-31 north of the Highway 58 bridge to Emerald Isle and March 1-15 south of the Highway 58 bridge); a 5-inch minimum size limit for mature female crabs statewide; retain the prohibition on immature female hard crab harvest and the 5% cull tolerance established in the 2016 Revision to Amendment 2. These measures are estimated to result in a 2.4% harvest reduction from 2016 landings. Other measures selected were to: have the season closures replace the annual pot closure period and adopt the adaptive management framework based on the peer-reviewed and approved stock assessment.

2) Non-quantifiable management measures: While not having quantifiable harvest reductions, several additional management measures were identified that could help improve the condition of the blue crab stock. The selected management strategy includes the following: retain a minimum number of 3 cull rings per pot with one in the modified corner position and to prohibit the harvest of dark sponge crabs from April 1 to 30 measures established in the 2016 Revision to Amendment 2; and removing the cull ring exemptions for the Newport River and eastern Pamlico Sound.

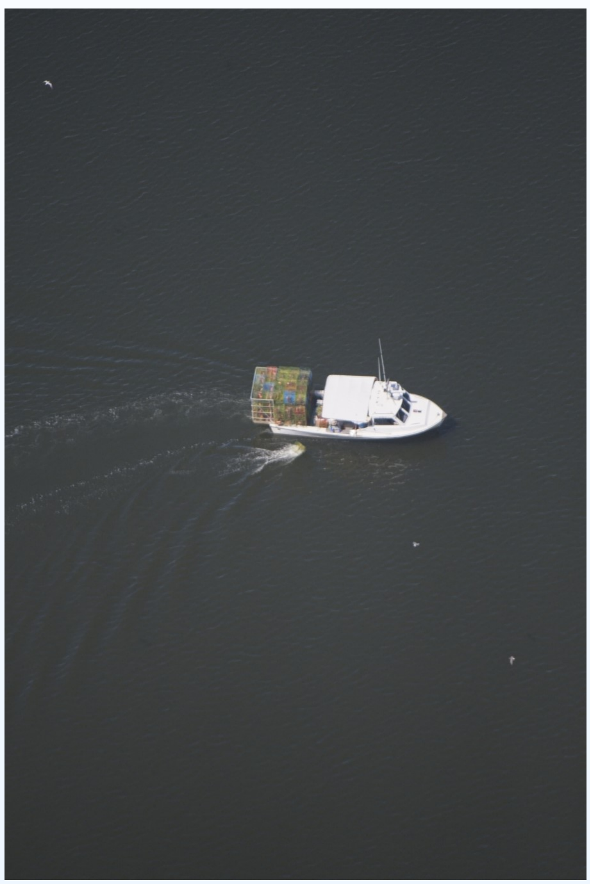

BLUE CRABS
Photo By: Corrin Flora

3) Water quality: Negative impacts on blue crab from poor water quality have been widely documented and strategies were developed for the N.C. Marine Fisheries Commission (NCMFC) to pursue to improve water quality. Strategies selected were: highlight problem areas and advise other regulatory agencies; push to create an interagency work group; support the Clean Water Act; task the CHPP steering committee to prioritize blue crab water quality impacts; send letters to other state agencies sharing concerns about water quality and Best Management Practices; invite other agencies to future NCMFC meetings to present their efforts to address water quality; and initiate public outreach on how to report crab and fish kills.

4) Crab spawning sanctuaries: Research has shown the existing crab spawning sanctuaries are largely ineffective due to their small size and that expanding the sanctuary system as well as establishing migration corridors will increase the number of mature females reaching the spawning grounds. The selected management strategy includes: maintain the current sanctuary boundaries for Oregon, Hatteras, and Ocracoke inlets; move the Drum Inlet sanctuary boundary to encompass Ophelia Inlet; expand the Barden Inlet sanctuary boundary; and designate new crab spawning sanctuaries around Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Cape Fear River, Shallotte, Lockwood Folly, and Tubbs inlets. The new crab spawning sanctuaries will be closed from March 1 to October 31 with the same restrictions as previously existing sanctuaries.

5) Diamondback Terrapin Management Areas framework : The NCMFC selected management strategy initially adopted in the 2013 Blue Crab FMP Amendment 2. Amendment 2 granted proclamation authority for the director of the North Carolina Division of Marine Fisheries (NCDMF) to require the use of terrapin excluder devices in crab pots. This 8-step framework consists of the following criteria: determine NCDMF approved terrapin .excluder device types and sizes to be required; determine dates when terrapin excluder devices will be required; identify the zone of potential diamondback terrapin interaction with crab pots; validate diamondback terrapin presence and overlap with zone of potential crab pot interaction; determine appropriate Diamondback Terrapin Management Area (DTMA) boundaries; develop initial issue paper detailing the proposed DTMA that will be presented to the appropriate regional committee and receive public comment; NCMFC review documents and take action to adopt, adopt with modification, or deny proposed DTMA; and implement adopted DTMA by proclamation and incorporate the finalized issue paper as a revision to the FMP.

6) Bottom disturbing gear: To reduce the habitat impacts from the blue crab fishery, the use of bottom disturbing gear, specifically dredges and trawls, was examined. The selected management strategy includes: retain the prohibition on targeted crab dredging established in the 2016 Revision to Amendment 2; reduce the crab bycatch limit from oyster dredges to 10% of the combined crab and oyster catch or 100 pounds, whichever is less; and to prohibit the use of crab trawls in areas where shrimp trawls are prohibited in the Pamlico, Pungo, and Neuse rivers.



COMMERCIAL CRAB BOAT
Photo By: Terry West

INTRODUCTION

This is Amendment 3 to the N.C. Blue Crab Fishery Management Plan (FMP). The last review of the plan concluded in November 2013 and resulted in Amendment 2 to the plan. There was a revision to Amendment 2 in May 2016 to implement management changes resulting from the adaptive management strategy in Amendment 2. That strategy relied on the Traffic Light Stock Assessment to provide information on the relative condition of the stock. In August 2016, the N.C. Marine Fisheries Commission (NCMFC) directed the next review of the plan to begin immediately instead of in 2018, despite the five-year span statutorily allowed. In Amendment 3, this management strategy is replaced by an adaptive management framework based on a comprehensive stock assessment for blue crab that is updated at least once in between scheduled plan reviews.

DEFINITION OF MANAGEMENT UNIT

The management unit includes the blue crab (*Callinectes sapidus*) and its fisheries in North Carolina coastal waters.

MANAGEMENT AUTHORITY

The Fisheries Reform Act of 1997 (FRA) and its subsequent amendments established the requirement to create FMPs for all of North Carolina's commercially and recreationally significant species or fisheries. The FRA "recognizes the need to protect our coastal fishery resources and to balance the commercial and recreational interests through better management of these resources" and requires the NCMFC "to provide fair regulation of commercial and recreational fishing groups in the interest of the public." Fishery management plans normally take about two years to complete and are required to be reviewed at least once every five years. Upon review, amendment of a plan is required when changes to management strategies are necessary. Through this process, the commission also has authority to implement federal fishery regulations (as minimum North Carolina standards) through the N.C. Fishery Management Plan for Interjurisdictional Fisheries, which selectively adopts management measures contained in approved federal Council or Atlantic States Marine Fisheries Commission (ASMFC) FMPs by reference. The goal of FMPs is to provide direction for the management of a fishery and to ensure long-term viability of North Carolina fisheries. It is a science-based management approach designed to include balanced stakeholder input from all sides, to look at the available data, to recognize the gaps, and to agree to the best possible path to manage the fisheries while acknowledging and minimizing impacts to various groups.

Under G.S. 113-182.1, each FMP shall contain necessary information pertaining to the fishery or fisheries, as well as include conservation and management measures that will provide the greatest overall benefit to the State, particularly with respect to food production, recreational opportunities, the protection of marine ecosystems, and that will produce a sustainable harvest. For these purposes, data are gathered, analyzed, interpreted, and management measures implemented. The division is empowered to collect scientific and statistical information as may be needed to determine conservation (G.S. 113-131; G.S. 113-181) FMPs are the ultimate product that bring all the information and considerations into one document for a species.

North Carolina's coastal fishery resources (the "fish") exist within a system of interdependent habitats that provide the basis for long-term fish production available for use by people (the "fisheries"). The FRA laws also recognized the importance of having sufficient quantity of quality habitat to support fish species throughout their life history. Because of this relationship between habitat and fish populations, the law contains the directive to protect and enhance habitats supporting coastal fisheries through the creation of Coastal Habitat Protection Plans (CHPP, G.S. 143B-279.8).

While much of the concern over declining fish stocks has been directed at overfishing, habitat loss and degradation may make a stock more susceptible to decline. The effect of habitat loss and degradation can be indicated by the lack of recovery of certain stocks after fishing pressure is reduced. The CHPP law specifically requires identification of "existing and potential threats to the habitats" and "actions to protect and restore the habitats" (G.S. 143B-279.8). Under the law the NCMFC shall ensure, to the maximum extent practicable, their actions are consistent with the Coastal Habitat Protection Plan and shall adopt rules to implement Coastal Habitat Protection Plans in accordance with Chapter 150B of the General Statutes. Either the FMP or CHPP statutes may provide the management authority for requiring habitat measures, but generally, the FMP authority has only been employed when there is a specific detrimental habitat threat from a fishery.

The N.C. General Assembly enacts fisheries statutes, or laws, and provides the NCMFC authority to adopt rules to implement those statutes. These rules are found in Chapters 03 and 18 of Title 15A of the N.C. Administrative Code. The N.C. Department of Environmental Quality (NCDEQ) is the parent agency of the commission and the N.C. Division of Marine Fisheries (NCDMF). The commission is responsible for managing, protecting, preserving, and enhancing the marine and estuarine resources under its jurisdiction. In support of these responsibilities, the division conducts management, enforcement, research, monitoring, statistics, and licensing programs to provide information on which to base decisions on rule-making. The division presents information to the commission and department in the form of fishery management and coastal habitat protection plans and proposed rules. The division also administers and enforces the commission's adopted rules. Another tool the state uses to manage fisheries is the proclamation. The commission has the authority to delegate to the fisheries director the ability to issue public notices, called proclamations, suspending or implementing particular commission rules that may be affected by variable conditions. The proclamation authority granted to the fisheries director includes the ability to open and close seasons and fishing areas, set harvest and gear limits, and establish conditions governing various fishing activities. Proclamation authority and proclamation measures are codified in rules.

MANAGEMENT GOAL AND OBJECTIVES

The goal of the North Carolina Blue Crab Fishery Management Plan is to manage the blue crab fishery to achieve a self-sustaining population that provides sustainable harvest using science based decision making processes.

The following objectives will be used to achieve this goal.

1. Implement management strategies that maintain/restore the blue crab spawning stock with multiple cohorts and adequate abundance to prevent recruitment overfishing.
2. Restore, enhance, and protect habitat and environmental quality necessary to maintain or increase growth, survival, and reproduction of the blue crab population.
3. Use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the blue crab fishery and its ecosystem impacts.
4. Promote stewardship of the resource through increased public awareness regarding the status and management of the blue crab fishery, including practices that minimize bycatch and discard mortality.

FISHERY MANAGEMENT PROGRAM IMPLEMENTED UNDER AMENDMENT 2 (2013)

MANAGEMENT MEASURES IN PLACE UNDER AMENDMENT 2 (2013)

All management authority for the North Carolina blue crab fishery is vested in the State of North Carolina. The NCMFC adopts rules and policies and implements management measures for the blue crab fishery. See Appendix 4 for a list of statues, rules, and regulations under Amendment 2 to the N.C. Blue Crab FMP. This summary does not maintain exact language and should not be relied upon for legal purposes. See North Carolina General Statutes, North Carolina Administrative Code and Proclamations for exact language. There are no federal or interstate FMPs that apply specifically to the blue crab fishery in North Carolina.

BLUE CRAB
Photo By: Jeff Dobbs

Amendment 2 to the N.C. Blue Crab FMP was adopted in November 2013 (for a timeline of plans, amendments, and related documents see Appendix 2). This amendment replaced the spawner index trigger with an adaptive management framework based on an annual Traffic Light Stock Assessment update, provided management recommendations, explored issues affecting the fishery, and listed research recommendations to fill data needs. Rules established in Amendment 2 went into effect April 2014.

Management changes included: opening the Pungo River to pots, closing Lower Broad Creek to pots, modifying crab dredging rules to conform with current harvest management, incorporating the Pamlico Sound four-inch crab trawl line into rule, redefining criteria exempting escape rings to unbaited pots and pots baited with a male crab, repealing proclamation authority allowing escape ring requirement, exemption to harvest peeler crabs, adopting no trawl line boundaries in the Pamlico Sound and Newport River for areas where escape ring closures are allowed, modification of trawl nets rule to identify Pamlico, Back, and Core sounds as areas that can open under proclamation for peeler crab trawling, modification to clearly state in rule the intent of the exceptions, culling tolerance, separation requirements for various crab categories, and established proclamation authority to require terrapin excluders (once a framework of criteria and excluder specifications were approved by the NCMFC).

In November 2016, adaptive management measures were implemented under the authority of Amendment 2. These included: reducing the cull tolerance from 10% to 5%, requiring an additional escape ring mounted in the upper chamber within one full mesh of the corner and divider of the pot, eliminating harvest of immature female hard crabs, prohibiting the harvest of dark sponge crabs (brown and black) from April 1 through April 30, and prohibiting harvest of crabs with dredges except incidental to lawful oyster dredging. All adaptive management measures became effective June 6, 2016 except for the additional cull ring which was delayed until January 15, 2017. This delay coincided with the annual pot closure period to allow fishermen time to modify pots.

COMPLIANCE AND ENFORCEMENT

There are two main sources of data necessary for fisheries management and evaluated for each FMP: fishery dependent and fishery independent data. Fishery dependent data are derived from the fishing process itself and are collected through such avenues as self-reporting, fish house surveys, onboard observers, telephone surveys, or vessel-monitoring systems. Fishery dependent sampling allows managers to account for sources of removals and the size and age structure of those removals. Fishery independent data comes from research and monitoring surveys conducted by state agencies. Scientists take samples throughout the potential range of the target fish(s) based on statistically valid sample designs that are not influenced by changes in fishing activity. Fishery independent sampling allows managers to monitor trends in the relative abundance of a species. Fishery dependent and independent sampling complement one another to provide a more complete picture of the condition of a fish stock. Dependent sampling intended to monitor trends in relative abundance can be biased by changes in gear specifications, fishing effort, areas fished, level of expertise of fishermen, technology, etc.

The division's License and Statistics Program is another source of fishery dependent information. The number of licenses issued to various types of fishermen such as the Standard Commercial Fishing License (SCFL), Retired Standard Commercial Fishing License (RSCFL), Commercial Fishing Vessel Registration (CFVR), Recreational Commercial Gear License (RCGL), and Coastal Recreational Fishing License (CRFL) may be used to determine the number of fishermen and vessels involved in various fisheries. These licenses are authorized in Chapter 113 of the North Carolina General Statutes.

The North Carolina Marine Patrol has officers working in three distinct law enforcement districts along the coast. In addition to checking commercial and recreational fishermen, officers patrol waterways, piers, and beaches in coastal areas. They also inspect seafood houses, vehicles transporting seafood, and restaurants across the state to ensure compliance with fisheries rules. In addition to the inspections listed above, the Marine Patrol have mandatory patrol responsibilities. The U.S. Food and Drug Administration requires North Carolina to patrol a certain number of hours in polluted waters each year. This is a primary function for the North Carolina Marine Patrol to ensure the health and welfare of consumers of North Carolina shellfish. The Marine Patrol also assists the observer program with gill net observations to ensure the division meets the required observer coverage as required by its federal Incidental Take Permits (ITPs). Failure to follow the requirements of the ITPs through lack of sufficient observer coverage could cause the estuarine gill net fishery to close completely.

BLUE CRABS

Photo By: Jeff Dobbs

DESCRIPTION OF THE STOCK

BIOLOGICAL PROFILE

Physical Description

Blue crabs are one of the most recognizable species of North Carolina. A swimming crustacean sought after for tender sweet meat, blue crabs have a carapace (shell) which has nine marginal teeth, the final one forming a distinct point. The carapace varies from blue to dark olive green. Blue crabs have five pairs of legs: bright blue claws often having red tips, three pairs of walking legs, and specially adapted paddle-shaped rear swimming legs. Male and female blue crabs are easily identified by the shape of the apron on their abdomen (underside). A male crab is easily recognized by the T-shaped apron (Figure 1 A). The immature female apron is triangular-shaped and held tightly against the abdomen (Figure 1 B). The mature female's apron becomes rounded and can be easily pulled away from the body after the final molt (Figure 1 C). When mature females develop an egg mass (sponge) it is visible beneath the apron ranging from bright orange to black (Figure 1 D).

Scientific Name

The scientific name of the blue crab is *Callinectes sapidus*. This translates to "savory beautiful swimmer." This description remarks on the remarkable coloration, the delicious meat, and the excellent swimming ability of the crab. The paddle-shaped rear swimming legs of blue crabs allow them to move through the water more than just walking on the bottom.

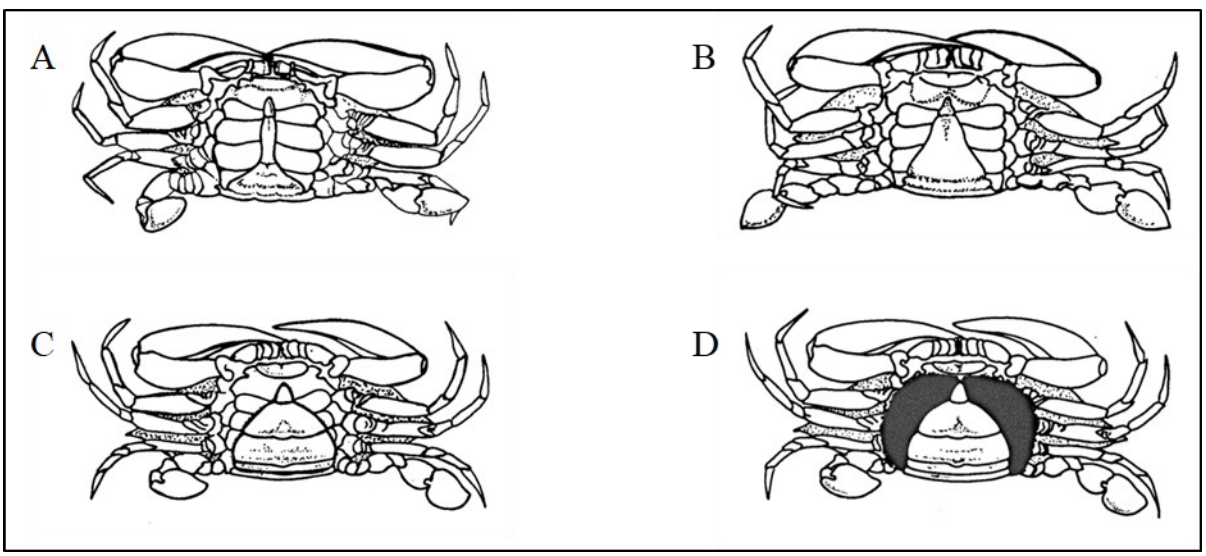


Figure 1 Apron shape differences between male and female blue crabs and immature and mature female blue crabs. A. "Jimmy" – male blue crab. B. "She-crab" – immature female blue crab. C. "Sook" – mature female blue crab. D. "Sponge crab" – Egg bearing mature female blue crab.

Distribution

The first larval stage (zoea) of blue crabs occurs offshore for several weeks where it undergoes several developmental stages before metamorphosing (transforming) into the next stage, called megalopae (1; 2). Because of the lack of inlets in Albemarle Sound, megalopae are transported primarily into Pamlico Sound, North Carolina via onshore wind events and nighttime incoming spring tides (3), which may be overshadowed by tropical storms, depending on frequency and wind direction (4). Megalopae then settle in seagrass beds in the seaward portion of the sounds before exhibiting density-dependent secondary dispersal resulting in juveniles being widely distributed throughout the estuaries of North Carolina (5). This means that as more crabs enter grass beds and crabs grow, they will begin to migrate to areas with fewer crabs. Decreases in salinity and the presence of bottom structure encourage settlement after this secondary migration. Therefore, crabs begin to prefer the fresher waters of the rivers and western portions of the sounds. After growth and maturation, females migrate to spawn in the high-salinity waters near the inlets (6). Other studies have also shown that the migratory behavior of mature female blue crabs continues between clutches (batch of eggs), and spawning females are continually moving seaward through the spawning season (7; 8; 9). Males do not migrate regularly as adults (10).

Habitat

Blue crabs require both inshore brackish waters and high salinity ocean waters during their life cycle (6). The preferred habitat of blue crabs is tidal marsh estuaries characterized by soft mud bottom and waters of moderate salinity (11). Juvenile blue crabs use seagrass beds and areas of high detritus to grow and avoid predators (12). Adult blue crabs have different habitat preferences by sex and salinity. Mature female blue crabs are more commonly found in higher salinity waters (>10 ppt) near inlets and the eastern side of the sounds while males prefer lower salinities (3 to 15 ppt) predominantly in the rivers and on the western side of the sounds.

Reproduction

Blue crabs mature between one and two years of age in North Carolina (13). Estimates of length at 50% maturity range from 3.9 in (98.8 mm) in 1999 to 4.9 in (125.7 mm) in 2015. Mating occurs during the spring or summer in brackish estuarine waters as females molt into maturity (14; 6). Spawning typically occurs within two months after mating if mating occurs early in the growing season; however, females can retain sperm through winter for spawning the following spring (15; 14). Spawning is initiated after migration to high-salinity areas near oceanic inlets. In the Chesapeake Bay, Prager et al. (16) found that fecundity (fertility) was significantly related to carapace width and estimated that average fecundity was 3,200,000 eggs per clutch. Females may spawn once or several times a season. In North Carolina, spawning has two peak pulses, April–June and August–September (9).

MALE AND MATURE FEMALE BLUE CRAB

Photo By: Jeff Dobbs

Age and Growth

Blue Crabs undergo seven to eight developmental stages [Figure 2; (17; 18; 2)]. Molting is a process of growth in blue crabs that requires shedding the hard exoskeleton. Fischler (19) reported an average life span of three years for blue crabs in North Carolina and a maximum size of around 8.5 in (217 mm). Estimates of maximum age have ranged between five and eight years for blue crabs in the Chesapeake Bay (20). Traditional growth models used for finfish are impractical to apply to crustaceans in general because the models assume growth is continuous (21; 22). For blue crabs and other crustaceans, the shell grows in discrete stages via shedding of the exoskeleton (molt). Carapace-width-to-length relationships have been estimated for blue crabs sampled from many estuaries throughout their range in the eastern United States (23; 24).

Molting

Larger crabs must store more nutrients than smaller crabs for molting. This is one reason as crabs grow there is more time between molts. Another term for molt is ecdysis.

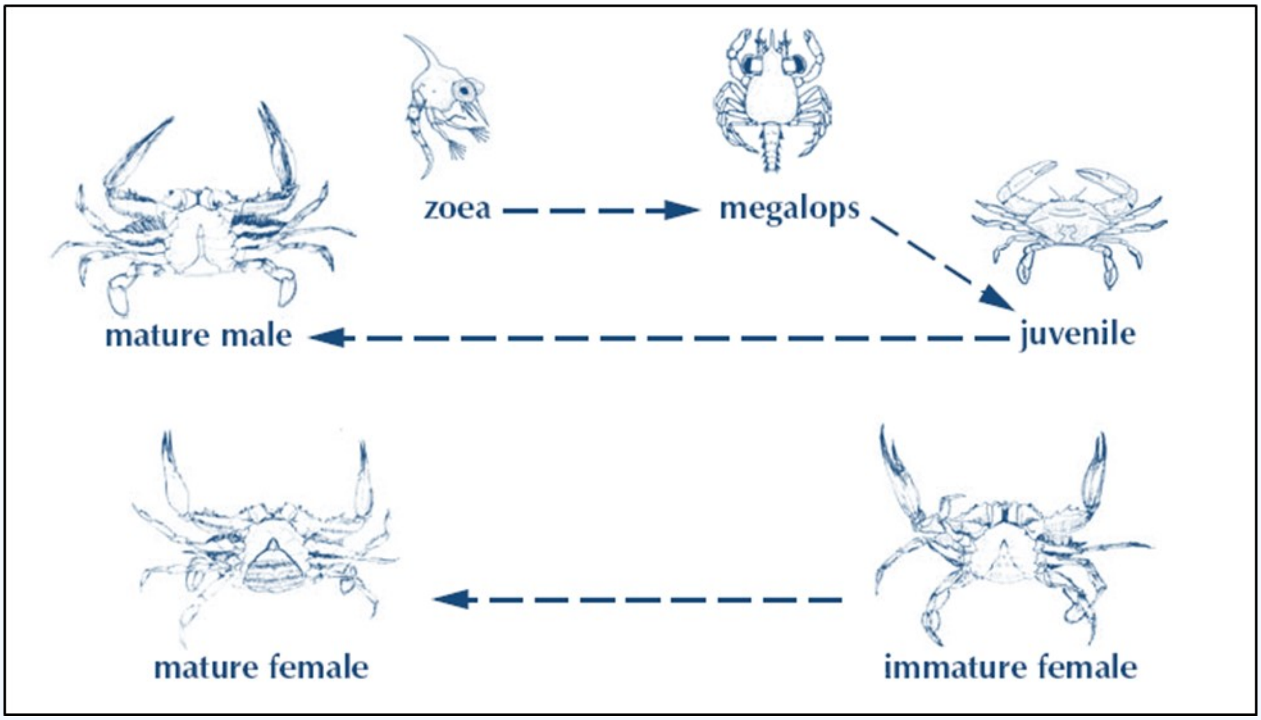


Figure 2 Lifecycle of the blue crab (*Callinectes sapidus*). (6).

Growth in blue crabs is rapid the first summer and is dependent on temperature, molt frequency, food quality and availability, and life stage. Optimum growth of blue crabs occurs at temperatures between 59°F (15°C) and 86°F (30°C), and growth stops when the temperature goes below 50°F (10°C) (25). In temperate regions, where winter temperatures regularly fall below this threshold, blue crabs bury into the sediment. During this dormant period, no growth occurs, thereby extending the time to reach maturity (26). Laboratory observations indicate that growth of blue crabs is 12% to 35% per molt (25). Most blue crabs go through 18 to 20 post-larval molts before becoming sexually mature (1).

Ageing crustaceans is notoriously difficult. Crustaceans do not have the persistent hard parts usually used to track and count rapid- and slow-growing periods to determine age. Recent advances in quantifying and calibrating oxidation products (lipofuscins) in nerve tissue have been promising as an alternative to the traditional carapace width estimators used to calibrate carapace width with age estimates. Lipofuscin extraction, however, is a new and costly technique that has not been widely used in ageing laboratories (27). A study in Florida, using two known age cohorts, found that lipofuscin indices were negatively correlated to age (28). These results suggest that more research is needed before this method can be used to age blue crabs.

Recently, another method that has been used to determine age in crustaceans is analyzing growth bands found around the calcified region of the eyestalk or gastric mill in shrimp, crabs, and lobsters (29). While this method has been successful to estimate age in longer-lived, cold water crustaceans like the American lobster (*Homarus americanus*), this method has not been tested in blue crabs.

Predator-Prey Relationships

Blue crabs consume a wide variety of food, fulfilling roles as predators and detritivores (animals that feed on dead organic material). They are large consumers of annelid worms (bristle worms, leeches, and other segmented worms), crustaceans, live or dead fish, vegetation, detritus, and feed heavily on oyster spat and juvenile clams (30). Bivalve mollusks (clams, oysters, mussels, and scallops) are a major portion of blue crab diets (31; 32; 33). They are also cannibalistic, and larger crabs are capable of exhibiting a check on population growth by consuming large amounts of small crabs and juveniles. Blue crabs are a part of the diets of many recreationally important species, including striped bass, black drum, red drum, bluefish, southern flounder, and Atlantic croaker (34).

BAY SCALLOPS

Photo By: NCDMF staff

STOCK STATUS

Stock Unit Definition

The unit stock includes all blue crabs in North Carolina coastal fishing waters.

Assessment Methodology

A comprehensive stock assessment approach, the sex-specific two-stage model, was applied to available data to assess the status of North Carolina's blue crab stock from 1995 to 2016. Data were available from commercial fishery monitoring programs and several fishery independent surveys. The two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, and thus, provided a comprehensive assessment of blue crab status in North Carolina. The hierarchical Bayesian approach was used to estimate model parameters, which can incorporate uncertainty associated with the data and model assumptions (35). The stock status of North Carolina blue crab in the current assessment (36) was determined based on maximum sustainable yield (MSY).

Current Stock Status

Based on the results of the assessment, the North Carolina blue crab stock in 2016 is overfished with a probability of 0.98, given the average spawner abundance in 2016 being estimated at 50 million mature female blue crabs (below the threshold estimate of 64 million). Overfishing is also occurring in 2016 with a probability of 0.52, given the average fishing mortality in 2016 being estimated at 1.48 (above the fishing mortality threshold estimate of 1.46; (35).

DESCRIPTION OF THE FISHERIES

Fishery Monitoring

NCDMF monitors commercial landings and fishing effort through a trip ticket program. Through this program, NCDMF collects information about commercial fishermen's harvest (i.e., what it is, where it was caught, how it was caught, and how much was caught) from licensed seafood dealers. NCDMF also conducts economic research pertaining to North Carolina and Atlantic coastal fisheries resources using information from the trip ticket program and mail or phone surveys.

A more in-depth analysis and discussion of North Carolina's commercial and recreational blue crab fisheries can be found in earlier versions of the Blue Crab FMP (37; 11; 38); all documents are available on the NCDMF website at: http://portal.ncdenr.org/web/mf/fmps-under-development) or the License and Statistics Annual Report (39) produced by the division which can be found at: http://portal.ncdenr.org/web/mf/marine-fisheries-catch-statistics.

The socio-economic information presented is about the current fishery and is not intended to be used to predict potential impacts from management changes. However, this and other information pertaining to fishery management plans are included to help inform decision-makers regarding the long-term viability of the state's commercially and recreationally significant species or fisheries. For a detailed explanation of the methodology used to estimate the economic impacts please refer to the NCDMF License and Statistics Section Annual Report (39).

COMMERCIAL FISHERY

Blue crab supports the largest and most valuable commercial fishery in North Carolina, accounting for landings of 27.8 million pounds with an ex-vessel value of $26.9 million in 2016 (Table 1). North Carolina has historically accounted for approximately 22% of annual Atlantic coast blue crab landings since 1950 (Figure 3). Landings of blue crab in North Carolina have fluctuated through time but peaked in the late 1990s (Figure 4).

BLUE CRABS

Photo By: Corrin Flora

Table 1 Blue crab commercial landings (millions of pounds) and value (millions of dollars) for hard, soft, and peeler crabs combined from major blue crab producing states, 2007-2016. Source: (40)

State \ Year	2007	2008	2009	2010	2011	2012
Alabama	2.6 / $1.7	1.8 / $1.5	1.5 / $1.0	0.9 / $0.7	1.6 / $1.1	1.3 / $1.0
Delaware	3.8 / $5.3	3.5 / $4.6	3.4 / $5.4	4.1 / $6.0	3.5 / $4.8	4.6 / $6.7
Florida East Coast	4.1 / $4.9	3.3 / $4.3	1.6 / $2.4	2.6 / $3.4	3.2 / $4.2	3.4 / $4.7
Florida West Coast	6.1 / $5.8	2.7 / $3.3	3.4 / $4.2	5.8 / $6.7	6.8 / $7.7	4.2 / $5.1
Georgia	4.4 / $3.8	4.2 / $3.9	3.6 / $3.8	2.3 / $2.6	3.4 / $3.3	4.3 / $4.3
Louisiana	45.1 / $35	41.7 / $32.2	53.1 / $37.3	30.8 / $30.3	43.9 / $36.8	46.3 / $43.9
Maryland	30.8 / $41.7	34.9 / $50.1	38.8 / $52	66.3 / $79.1	51.2 / $60.3	43.7 / $60.5
Mississippi	0.7 / $0.7	0.5 / $0.4	0.5 / $0.6	0.4 / $0.4	0.4 / $0.3	0.8 / $0.7
New Jersey	4.6 / $5.5	5.8 / $7.3	0.3 / $0.2	9.5 / $12	9.6 / $9.4	7.4 / $10.0
New York	0.7 / $1.2	0.5 / $0.9	0.9 / $1.2	1.0 / $1.6	0.5 / $0.8	0.1 / $0.2
North Carolina	21.4 / $21.4	32.9 / $27.6	29.7 / $27.4	30.7 / $26.4	30.0 / $21.3	26.8 / $22.8
South Carolina	4.1 / $3.5	4.5 / $4.2	4.0 / $4.1	3.3 / $3.6	5.4 / $5.1	5.9 / $5.8
Texas	3.5 / $2.8	2.6 / $2.3	2.8 / $2.5	3.4 / $3.1	2.9 / $2.8	2.9 / $2.9
Virginia	25.1 / $15.8	23.2 / $18	32.8 / $21.2	38.5 / $29.1	39.7 / $26.3	33.1 / $24.6

State \ Year	2013	2014	2015	2016	Average	Percent of Total Landings
Alabama	1.0 / $1.0	1.2 / $1.3	1.3 / $1.2	1.9 / $1.8	1.5 / $1.2	0.9%
Delaware	2.5 / $4.6	2.0 / $4.4	2.1 / $4.5	3.9 / $7.9	3.3 / $5.4	2.0%
Florida East Coast	2.2 / $3.8	1.5 / $3.1	1.6 / $3.4	1.6 / $3.2	2.5 / $3.7	1.5%
Florida West Coast	4.5 / $6.5	4.5 / $7.4	4.9 / $8.5	3.5 / $6.1	4.6 / $6.1	2.8%
Georgia	3.2 / $4.0	2.7 / $3.8	2.9 / $4.2	3.1 / $3.7	3.4 / $3.7	2.0%
Louisiana	39.2 / $51.6	43.2 / $66.7	41.3 / $58.1	40.1 / $49.4	42.5 / $44.1	25.3%
Maryland	24.2 / $50.0	24.7 / $52.8	28.7 / $52	34.9 / $60.7	37.8 / $55.9	22.5%
Mississippi	0.4 / $0.4	0.6 / $1.0	0.8 / $1.2	0.8 / $0.9	0.6 / $0.7	0.3%
New Jersey	4.4 / $8.1	3.2 / $4.1	7.2 / $8.7	6.9 / $7.7	5.9 / $7.3	3.5%
New York	0.1 / $0.2	0.3 / $0.6	0.2 / $0.4	0.2 / $0.4	0.5 / $0.8	0.3%
North Carolina	22.2 / $30.0	26.2 / $34.0	32.1 / $34.0	25.5 / $24.1	27.8 / $26.9	16.5%
South Carolina	5.1 / $6.4	3.8 / $5.8	3.7 / $4.8	4.4 / $5.5	4.4 / $4.9	2.6%
Texas	1.9 / $2.3	2.2 / $3.1	4.3 / $5.5	5.0 / $6.4	3.2 / $3.4	1.9%
Virginia	24.3 / $24.0	24.2 / $27.0	29.7 / $33.1	28.1 / $40.9	29.9 / $26	17.8%

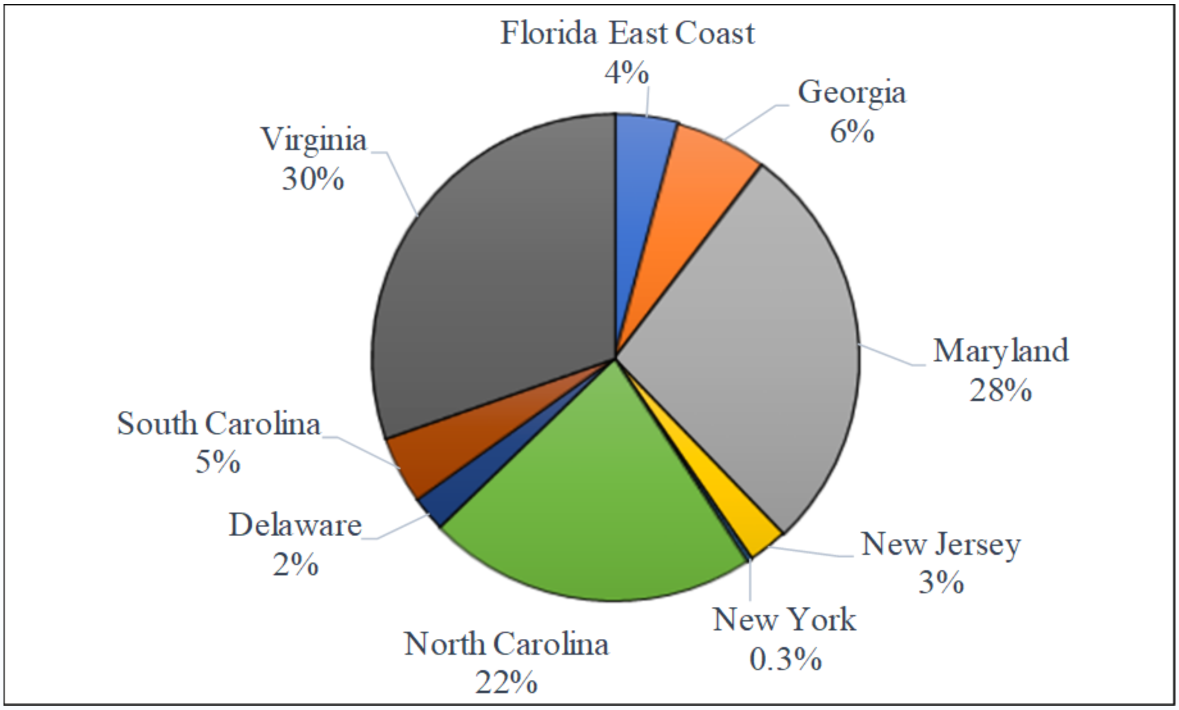


Figure 3 Average contribution to U.S. Atlantic coast blue crab landings by state, 1950-2016. Source: (40)

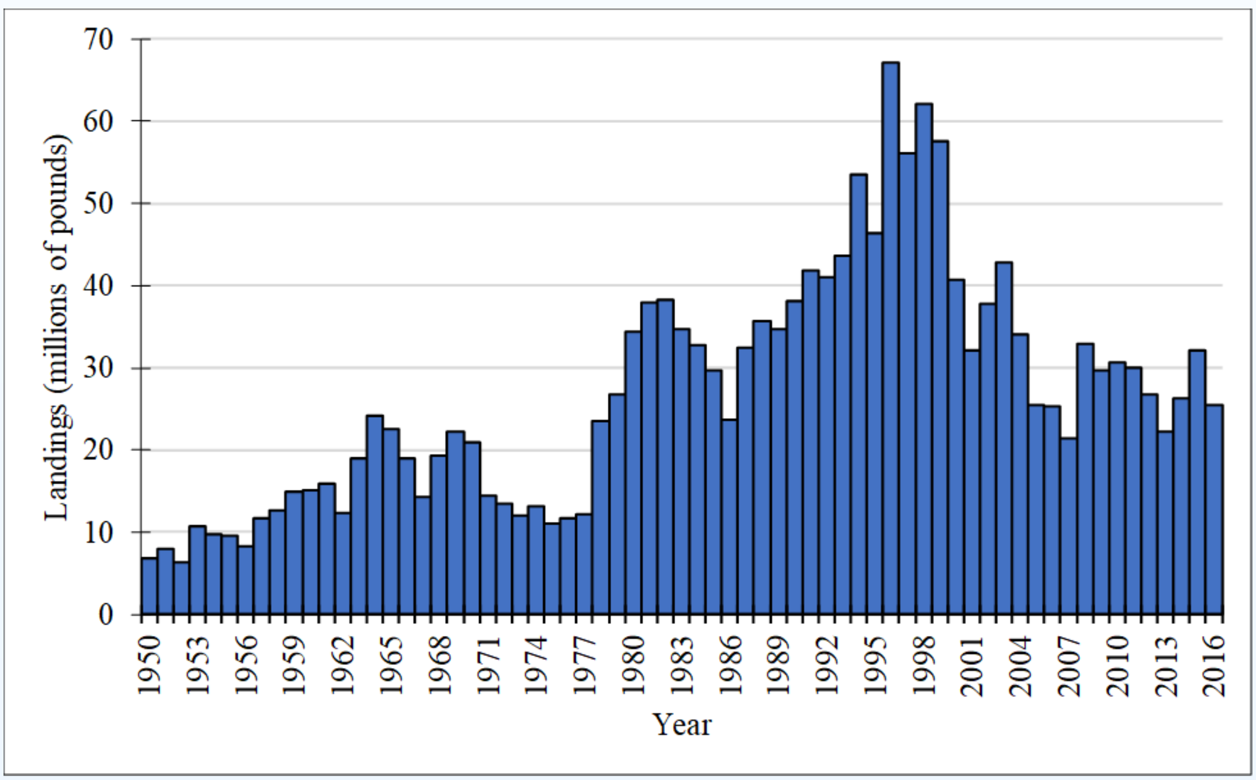


Figure 4 North Carolina annual blue crab commercial landings, 1950-2016. Source: (40)

Commercial Fishery Data Collection

In North Carolina, fishermen have been harvesting blue crabs commercially since the 1800s, with the earliest documented landings reported in 1889 (41). However, landings statistics are patchy prior to 1950. In 1994, the NCDMF implemented a mandatory trip ticket program to monitor commercial landings and fishing effort. Through this program, the NCDMF collects commercial landings data on a trip basis from licensed seafood dealers. The NCDMF requires dealers purchasing blue crabs from commercial fishermen to submit trip tickets that capture information about their catch, such as what was harvested, where it was caught, how it was caught, and how much was harvested. Commercial fishermen who sell their catch directly to consumers are required to possess a dealer's license and submit trip tickets.

Data Collection

Starting in 1950, NOAA Fisheries began collecting annual commercial landings statistics from seafood dealers on a voluntary basis. In 1978, NCDMF joined NOAA Fisheries in a cooperative statistics program and took over collection of commercial landings statistics.

The NCDMF's License and Statistics section conducts economic research pertaining to North Carolina and Atlantic coastal fisheries using information from the trip ticket program and surveys. This section publishes results annually in the License and Statistics Annual Report (39; http://portal.ncdenr.org/web/mf/marine-fisheries-catch-statistics) and also provides information to NCDMF and other agencies to support scientific research and resource management.

Unless otherwise noted, all data presented in the following sections are from the NCDMF trip ticket program. Data are presented from 2007 to 2016. Trends are shown for the ex-vessel value and harvest volume is presented in pounds.

Annual Landings and Value

Average blue crab landings in North Carolina between 2007 and 2016 were 27.8 million pounds (Table 2). The lowest landings during this period was 21.4 million pounds in 2007 and the highest was 32.9 million pounds in 2008.

BUSHEL BASKET OF BLUE CRABS

Photo By: Jessica Lee

Annual ex-vessel value of commercial blue crab landings averaged $26.9 million from 2007 to 2016 (Table 2). Annual ex-vessel value reached a low of $21.3 million in 2011 and a high of $33.7 million in 2015.

Ex-vessel price per pound of blue crabs (ex-vessel value divided by annual commercial landings) average $0.97 per pound from 2007 to 2016 (Table 2). Ex-vessel price per pound reached a low of $0.71 per pound in 2011 and a high of $1.35 per pound in 2013.

Table 2 North Carolina commercial blue crab landings and value, 2007-2016.

Year	Harvest	Reported Ex-vessel Value	Reported Ex-vessel Price Per Pound	Inflation Adjusted Ex-vessel Value	Inflation Adjusted Price Per Pound
2007	21,424,960	$21,431,955	$1.00	$26,480,167	$1.24
2008	32,916,691	$27,555,386	$0.84	$30,679,127	$0.93
2009	29,707,232	$27,428,995	$0.92	$30,805,897	$1.04
2010	30,683,011	$26,543,791	$0.87	$28,401,979	$0.93
2011	30,035,392	$21,282,264	$0.71	$21,190,451	$0.71
2012	26,785,669	$22,806,938	$0.85	$22,806,938	$0.85
2013	22,202,623	$30,006,447	$1.35	$30,308,482	$1.37
2014	26,230,965	$34,027,403	$1.30	$32,887,456	$1.25
2015	32,134,501	$33,724,424	$1.05	$33,616,270	$1.05
2016	25,459,475	$24,112,715	$0.95	$24,116,347	$0.95
Average	27,758,052	$26,892,032	$0.97	$28,129,312	$1.01

Landings by Crab Type

In North Carolina, fishermen harvest hard-shell, soft-shell, and peeler blue crabs (Figure 5). Peeler blue crabs still have a hard shell but are in the pre-molt stage (i.e., a white line is present on the swimming leg). Hard-shell blue crabs are typically sold to: 1) wholesale/retail seafood dealers that grade, pack, and ship blue crabs to live markets or crab processors, 2) retail seafood dealers, and 3) consumers directly.

Hard-shell blue crabs sold to live markets are typically graded by size. Grading occurs either onboard the vessel or at the dock. Graded sizes vary based on crab abundance and market demands but generally include:

- Number 1 males: greater than 5.75 inches carapace width (CW)
- Number 2 males: 5.25 to 6 inches CW
- Number 3 females: greater than 5.5 inches CW
- Straights and Culls: smaller crabs destined for processing

Blue crab fishermen also cull and shed peeler blue crabs either in their own facility or sell them to other shedding operations.

Hard-shell blue crab landings accounted for 97.0% of the cumulative landings and 88.2% of the cumulative ex-vessel value of blue crabs harvested in North Carolina from 2007 to 2016. Average hard shell blue crab landings during this period were 26.9 million pounds (Table 3). Landings fluctuated from a low of 20.6 million pounds in 2007 to a high of 32.3 million pounds in 2008. During this period, the ex-vessel price per pound ranged from a low of $0.62 in 2011 to a high of $1.23 in 2013.

The harvest of soft-shell and peeler blue crabs is minor compared to hard-shell blue crabs but they are an economically important sector of the blue crab fishery as they tend to command a higher market price. Soft-shell crabs primarily come from crab shedding operations. In these operations, peeler blue crabs are placed into open or closed recirculating tank systems and sorted according to molt stage. Once a crab sheds, it is immediately removed because it is very vulnerable to predation from other crabs and to prevent the shell from hardening to a point the crab becomes unmarketable.

Soft-shell blue crabs comprised 1.2% of the total landings and 6.8% of the total ex-vessel value of blue crab landings from 2007 to 2016. Average soft-shell blue crab landings during this period were 323,080 pounds (Table 3). Landings fluctuated from a low of 198,876 pounds in 2009 to a high of 446,405 pounds in 2011. The ex-vessel price per pound averaged $5.72 from 2007 to 2016, almost six and half times the average ex-vessel price per pound for hard-shell blue crabs during the same period.

Peeler blue crabs accounted for 1.8% of the total landings and 5.0% of the total ex-vessel value of blue crab from 2007 to 2016. During this period, average peeler blue crab landings ranged from a low of 351,995 pounds in 2008 to a high of 706,671 pounds in 2015 (Table 3). From 2007 to 2016, the real ex-vessel price per pound for peeler blue crabs averaged $2.66, roughly three times the average ex-vessel price per pound for hard-shell blue crabs during this period.

Table 3 Landings and real ex-vessel price per pound of North Carolina blue crabs by type, 2007-2016.

Year	Hard-shell	Peeler	Soft-shell
2007	20,562,166 / $0.88	498,917 / $2.38	363,918 / $5.87
2008	32,338,899 / $0.79	351,995 / $2.51	225,822 / $5.51
2009	29,140,483 / $0.86	367,904 / $3.01	198,876 / $6.45
2010	29,794,332 / $0.80	568,228 / $2.11	320,480 / $4.82
2011	28,964,480 / $0.62	624,376 / $1.90	446,405 / $4.66
2012	25,991,391 / $0.78	468,867 / $2.37	325,426 / $4.60
2013	21,438,089 / $1.23	447,135 / $3.24	317,425 / $6.59
2014	25,242,662 / $1.19	621,046 / $3.12	367,284 / $5.82
2015	31,040,019 / $0.95	706,671 / $2.99	380,379 / $5.67
2016	24,732,129 / $0.84	445,843 / $2.95	284,786 / $7.24
Average	26,924,465 / $0.89	510,098 / $2.66	323,080 / $5.72

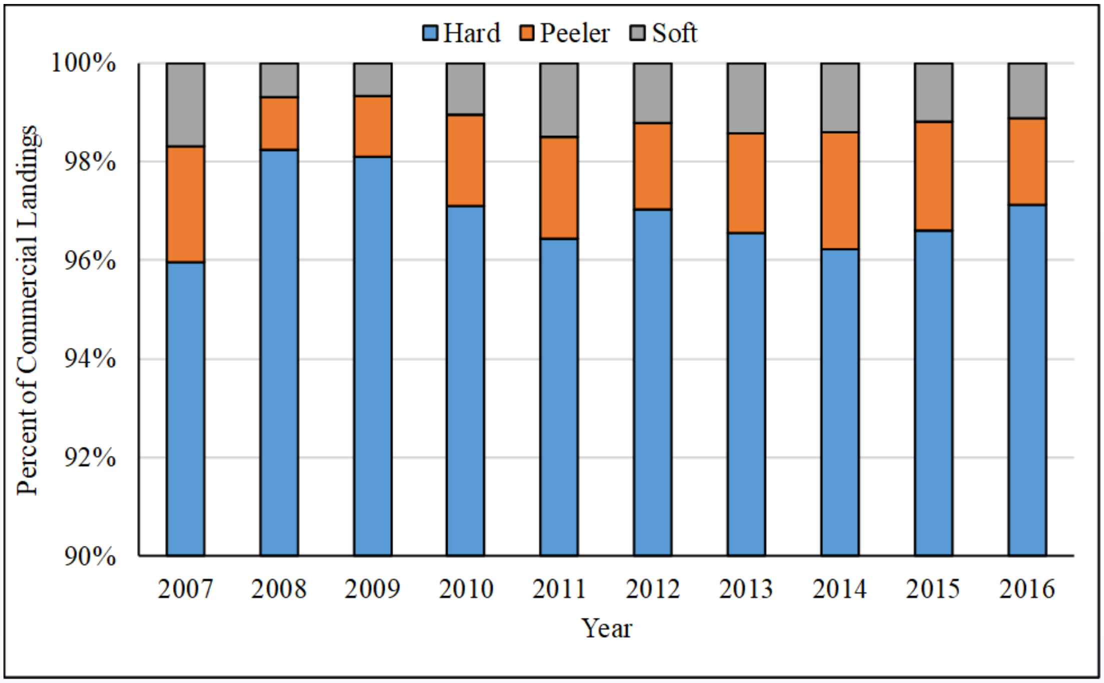


Figure 5 North Carolina blue crab commercial landings percent by type, 2007-2016.

Landings by Season

Commercial blue crab landings in North Carolina vary by season. Landings are lowest in January and February, averaging approximately 89,230 pounds and $78,159 monthly (from 2007 to 2016; Table 4). Average monthly landings are highest in the summer months: 4.2 million pounds and $4.1 million in June, 4.0 million pounds and $3.8 million in July, and 4.3 million pounds and $3.9 million in August.

Average ex-vessel price per pound also fluctuates seasonally (Table 4). From 2007 to 2016, average ex-vessel price per pound ranged from $0.70 per pound in November to $2.31 per pound in May.

Table 4 Average monthly blue crab landings (pounds), ex-vessel value, and ex-vessel price per pound, 2007-2016.

Month	Average Landings	Average Ex-vessel Value	Average Ex-vessel Price per Pound
January	84,046	$70,603	$1.16
February	94,413	$85,716	$1.40
March	645,065	$634,210	$1.59
April	967,654	$1,178,043	$2.16
May	3,189,032	$4,596,248	$2.31
June	4,232,447	$4,117,839	$1.58
July	3,989,698	$3,806,953	$1.36
August	4,273,003	$3,916,515	$1.43
September	4,138,995	$3,567,066	$1.26
October	3,705,524	$2,984,561	$0.87
November	1,845,994	$1,462,970	$0.70
December	592,208	$471,308	$0.90

Landings by Gear Type and Vessel Length

Early blue crab fishermen used baited trotlines to harvest hard-shell blue crabs in North Carolina (41). In the mid-1960s, crab pots became the most popular gear used in the blue crab fishery due to their efficiency. While several gear types are used to harvest blue crabs, most fishermen use crap pots, generally baited with Atlantic menhaden or other finfish. From 2007 to 2016, approximately 97% of the total blue crab landings have been harvested with crab pots (Table 5; Figure 6). Landings from other blue crab specific gears account for approximately 3% of the total landings, and all other commercial gears account for less than 1% of the total landings.

Overall, the majority of commercial blue crab landings in North Carolina are from vessels between 15 and 30 feet long. Vessels less than 15 feet long account for less than 1% of the landings on average from 2007 to 2016. Vessels 31 feet long and greater accounted for approximately 12% of the landings on average during this same period.

Table 5 Annual blue crab landings (pounds) by gear type, 2007-2016.

Year	Crab Pot	Peeler Pot	Crab Trawl	Peeler Trawl	Crab Dredge	Other	Total
2007	20,909,150	413,827	28,789	-	2,656	70,538	21,424,960
2008	30,967,910	293,679	1,557,934	-	-	97,169	32,916,691
2009	28,431,358	266,464	913,928	-	7,981	87,501	29,707,232
2010	29,789,952	489,097	286,653	2,746	52,769	61,794	30,683,011
2011	29,095,531	668,414	199,217	2,724	6,843	62,664	30,035,392
2012	26,247,049	457,413	7,608	2,466	2,335	68,798	26,785,669
2013	21,697,292	379,412	54,658	1,813	-	69,448	22,202,623
2014	25,471,904	637,572	38,059	1,843	10	81,577	26,230,965
2015	31,054,531	835,009	185,527	1,580	1,382	56,472	32,134,501
2016	24,754,952	503,728	163,250	1,323	2,958	33,264	25,459,475
Average	26,841,963	494,461	343,562	2,071	9,617	68,922	27,758,052

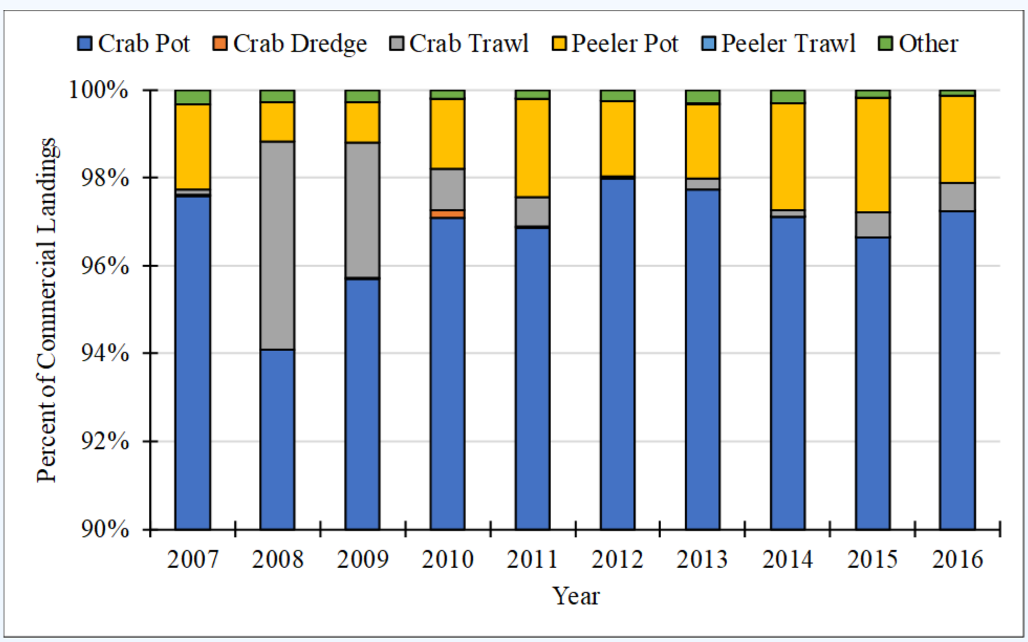


Figure 6 Percent of annual blue crab commercial landings by gear type, 2007-2016.

Landings by Area

Commercial fishermen in North Carolina are asked to identify the area in which they caught the majority of their catch during each trip. The Albemarle Sound (Albemarle Sound, Albemarle Sound Rivers, and Currituck, Roanoke, and Croatan sounds) and Pamlico Sound (Pamlico Sound and Pamlico Sound Rivers) estuary systems accounted for, on average, 93% of the total annual blue crab harvest from 2007 to 2016 (Table 6). During this time period, the average ex-vessel value was highest in the Currituck, Roanoke, and Croatan sounds, followed by Core-Bogue sounds, Albemarle Sound, White Oak River, and South, Pamlico Sound Rivers, Pamlico Sound, and Albemarle Sound Rivers.

Table 6 Blue crab landings (millions of pounds) and average ex-vessel price per pound by area, 2007-2016.

Year	Albemarle Sound Rivers	Albemarle Sound	Currituck, Roanoke, and Croatan Sounds	Pamlico Sound	Pamlico Sound Rivers	Core-Bogue Sounds	White Oak River and South	Statewide*
2007	0.8 / $0.70	10.9 / $1.02	3.1 / $1.24	1.7 / $0.96	3.2 / $0.90	0.5 / $0.77	1.3 / $0.87	21.4 / $1.00
2008	1.2 / $0.72	17.9 / $0.86	4.9 / $0.92	4.2 / $0.72	2.9 / $0.84	0.4 / $0.81	1.4 / $0.75	32.9 / $0.84
2009	1.7 / $0.66	15.1 / $0.96	5.6 / $1.03	3.3 / $0.77	2.2 / $0.91	0.4 / $0.88	1.4 / $0.83	29.7 / $0.92
2010	1.2 / $0.71	13.6 / $0.84	4.5 / $0.97	4.6 / $0.86	4.9 / $0.85	0.5 / $0.91	1.3 / $1.99	30.7 / $0.87
2011	1.6 / $0.47	12.3 / $0.71	4.2 / $0.84	5.0 / $0.68	5.0 / $0.70	0.5 / $0.64	1.4 / $0.77	30.0 / $0.71
2012	2.0 / $0.63	12.6 / $0.89	3.5 / $0.96	3.6 / $0.80	2.8 / $0.80	0.8 / $0.71	1.6 / $0.87	26.8 / $0.85
2013	2.5 / $1.16	11.3 / $1.40	2.7 / $1.39	2.5 / $1.25	1.3 / $1.54	0.6 / $1.27	1.3 / $1.26	22.2 / $1.35
2014	3.5 / $1.10	13.1 / $1.26	3.7 / $1.42	2.1 / $1.41	2.1 / $1.44	0.6 / $1.57	1.2 / $1.32	26.2 / $1.30
2015	4.1 / $0.72	13.6 / $1.06	4.5 / $1.20	3.5 / $1.03	4.6 / $1.07	0.7 / $1.32	1.2 / $1.30	32.1 / $1.05
2016	2.8 / $0.57	9.0 / $1.06	3.8 / $1.06	4.2 / $0.83	3.5 / $0.88	0.8 / $1.13	1.3 / $1.08	25.5 / $0.95
Average	2.1 / $0.74	12.9 / $1.00	4.0/ $1.10	3.5 / $0.93	3.3 / $0.99	0.6 / $1.00	1.3 / $1.00	27.8 / $0.98

*Ocean data are not presented, landings in the ocean averaged less than 8,000 pounds per year during this period.

Albemarle Sound

From 2007 to 2016, Albemarle Sound led all areas in blue crab landings, averaging just under 13 million pounds annually. Albemarle Sound is defined as Albemarle Sound proper as defined in the NCDMF Trip Ticket program. Landings peaked at 17.9 million pounds in 2008 and were lowest in 2016 at 9.0 million pounds. Seasonal landings follow similar trends as most areas with highest average landings levels from June through October.

Currituck, Roanoke, and Croatan Sounds

Blue crab landings from the Currituck, Roanoke, and Croatan sounds ranked second among all areas, averaging 4 million pounds annually. This area comprises only Currituck, Roanoke, and Croatan sounds. Landings peaked at 5.6 million pounds in 2009 and were lowest in 2013 at 2.7 million pounds.

Pamlico Sound

Blue crab landings from Pamlico Sound ranked third during this period averaging, 3.5 million pounds annually. Pamlico Sound is defined a Pamlico Sound and its associated bays as defined in the NCDMF Trip Ticket program. Landings peaked at 5.0 million pounds in 2011 and were lowest in 2007 at 1.7 million pounds.

Pamlico Sound Rivers

Blue crab landings from Pamlico Sound rivers ranked fourth among all areas, averaging 3.3 million pounds annually. Pamlico Sound rivers include the Pamlico, Pungo, Bay, and Neuse rivers. Landings peaked at 5.0 million pounds in 2011 and were lowest in 2013 at 1.3 million pounds.

Albemarle Sound Rivers

Blue crab landings from Albemarle Sound rivers ranked fifth during this period, averaging 2.1 million pounds annually. Albemarle Sound rivers include the Alligator, Chowan, Pasquotank, Perquimans, and Roanoke rivers. Landings peaked at 4.1 million pounds in 2015 and were lowest in 2007 at 0.8 million pounds.

White Oak River and South

Blue crab landings from the White Oak River and south ranked sixth among all areas, averaging 1.3 million pounds annually. This area includes the White Oak River and all waters south to the South Carolina state line. Landings peaked at 1.6 million pounds in 2012 and were lowest in 2014 and 2015 at 1.2 million pounds.

Core Sound and Bogue Sound

Blue crab landings from Core and Bogue sounds ranked last during this period, averaging 0.6 million pounds annually. The Core Sound and Bogue Sound area includes Core, Back, and Bogue sounds and the North and Newport rivers. Landings peaked at 0.8 million pounds in 2012 and 2016 and were lowest in 2008 and 2009 at 0.4 million pounds.

Commercial Crabbers

A fisherman must hold a Standard Commercial Fishing License or a Retired Standard Commercial Fishing License to land blue crabs commercially in North Carolina. Commercial licenses are sold on a fiscal year calendar, which runs from July 1 through June 30.

Demographic Characteristics

The average age of commercial fishermen involved in the blue crab fishery ranged from 45 years old in 2016 to 49 in 2012, 2013, and 2015 (Table 7). Most commercial fishermen are also male and Caucasian (Tables 8 and 9).

BLUE CRAB

Photo By: Jeff Dobbs

Table 7 Average age of commercial fishermen who harvested blue crab from 2007 – 2016.

Year	Average Age
2007	48
2008	48
2009	47
2010	47
2011	48
2012	49
2013	49
2014	48
2015	49
2016	45

Table 8 Number of commercial fishermen by gender who harvested blue crab from 2007 – 2016.

Year	Male	Female	Unknown
2007	888	60	5
2008	850	60	5
2009	926	60	6
2010	912	68	7
2011	861	60	5
2012	830	61	8
2013	801	57	8
2014	856	64	6
2015	847	66	13
2016	813	66	9

Table 9 Number of commercial fishermen by race who harvested blue crab from 2007 – 2016.

Year	African American	American Indian	Asian/Pacific Islands	Caucasian	Hispanic	Unknown
2007	23	1	61	853	4	10
2008	24	2	52	824	5	8
2009	20	3	57	901	2	9
2010	21	4	63	887	2	10
2011	21	4	59	835	1	6
2012	21	3	53	810	1	11
2013	23	3	46	781	1	12
2014	23	2	51	838	1	11
2015	21	2	53	832	1	17
2016	21	1	51	801	1	12

During the sale and renewal of commercial licenses, an economic survey is conducted that asks commercial fishermen if they obtain more than 50 percent of their income from commercial fishing. Most blue crab fishermen indicated they do generate more than 50 percent of their income from commercial fishing. However, the difference between the number of those fishermen indicating less than 50 percent of their income from commercial fishing and those indicating making more than 50 percent has been getting smaller in recent years (Table 10).

Table 10 Number of commercial fishermen who indicated they make less or more than 50 percent of their income from commercial fishing as indicated from the economic survey conducted during license sales and renewals from license years 2007 to 2016.

Year	Less than 50%	More than 50%	Unknown
2007	136	702	6
2008	187	774	5
2009	184	813	18
2010	181	846	14
2011	157	841	6
2012	149	771	15
2013	130	750	18
2014	163	748	38
2015	210	755	24
2016	255	697	17

Commercial Crabbers

A fisherman needs to hold a Standard Commercial Fishing License (SCFL) or a Retired Standard Commercial Fishing License (RSCFL) to land blue crabs commercially in North Carolina. Commercial licenses are sold on a fiscal year calendar, which runs from July 1 to June 30. The total number of SCFLs and RSCFLs issued over fiscal year 2007 to fiscal year 2016 ranged from 6,425 in 2016 to 6,906 in 2007 (Table 11). The number of participants with reported landings ranged from 863 in 2013 to 990 in 2009. Most participants who operate in the blue crab commercial fishery landed hard-shell blue crabs with the number of participants ranging from 815 in 2013 to 944 in 2010. The number of participants reporting landings from peeler and soft-shell crabs is much less. The number of participants reporting peeler crabs ranged from 476 in 2016 to 561 in 2009. For soft-shell crabs, the number of participants ranged from 209 in 2011 to 270 in 2009.

COMMERCIAL POTS BEING SET

Photo By: Jessica Lee

Table 11 Total number of SCFL/RSCFLs issued and participants landing blue crab.

Year	SCFL/RSCFLs Issued[1]	Participants w/Blue Crab Landings	Participants w/ Hard-Shell Crab Landings	Participants w/ Peeler Crab Landings	Participants w/ Soft-Shell Crab Landings
2007	6,906	952	890	548	270
2008	6,861	914	857	526	245
2009	6,827	990	943	561	245
2010	6,815	984	944	551	238
2011	6,819	925	883	511	209
2012	6,794	895	837	506	229
2013	6,699	863	815	502	253
2014	6,685	923	887	534	259
2015	6,635	923	883	534	241
2016	6,465	884	862	476	237
Average	6,751	925	880	525	423

[1] SCFL/RSCFLs are issued on a fiscal year (July 1 to June 30).

Most participants who land blue crabs live in the coastal counties of North Carolina. Over 73% of the participants who landed blue crabs in 2016 were from Dare (20%), Beaufort (14%), Carteret (11%), Hyde (7%), Currituck (6%), Pamlico (5%), Perquimans (5%), and Tyrrell (5%) counties.

Fishery Effort

The number of trips reporting landings of blue crabs averaged over 54,000 over the 2007 to 2016 period. The number of trips ranged from 51,707 in 2016 to 59,313 in 2009 (Table 12). The average landings per trip ranged from 398 pounds per trip in 2007 to 625 pounds per trip in 2008. The real value per trip ranged from $404 in 2011 to $585 in 2014.

Looking more specifically at the crab and peeler pot fishery, the average number of pots reported on trip tickets as being fished from 2007 to 2016 was over 13.6 million per year. The number of pots fished ranged from 12.2 million in 2013 to 16.4 million in 2015. The average number of pots fished per trip ranged from 241 pots per trip in 2007 to 293 pots per trip in 2015. The average blue crab catch per pot ranged from 1.70 pounds per pot in 2007 and 2014 to 2.50 pounds in 2008.

DERELICT CRAB POT

Photo By: NC Marine Patrol

Table 12 Annual trips, catch per trip, real value per trip, total number of pots, pots fished per trip, and catch per pot in the blue crab fishery.

Year	Trips[1]	Catch Per Trip[1]	Real Value Per Trip[1]	Total Pots Reported Fished[2]	Pots Per Trip[3]	Catch Per Pot
2007	53,833	398	$492	12,585,097	241	1.70
2008	52,654	625	$583	12,525,056	249	2.50
2009	59,313	501	$519	14,069,873	247	2.04
2010	54,977	558	$517	13,336,039	249	2.27
2011	52,406	573	$404	12,814,114	253	2.32
2012	52,697	508	$433	12,547,175	245	2.13
2013	52,631	422	$576	12,199,083	239	1.81
2014	56,217	467	$585	15,322,181	283	1.70
2015	57,603	558	$579	16,433,869	293	1.94
2016	51,707	492	$466	14,712,005	291	1.72
Average	54,404	510	$515	13,654,449	259	2.01

[1] The number of trips, catch per trip, and real value per trip is from all trips that recorded blue crabs across all gear types including pots, trawls, dredges, and other.

[2] The total number of pots reported fished is the sum of what was reported on trip tickets and duplicates the number of pots fished by an individual each time they fill out a trip ticket. For example, if a fishermen fishes 50 pots each trip and has 100 trips for the year it will calculated as 5,000 pots fished.

[3] The number of pots per trip is the average number of pots reported fished on trip tickets. This is not the same as the number of pots a fisherman may have in the water. For example, a fisherman may have 500 pots in the water but only fish 250 pots on a particular day, so the number of pots fished for the trip would be 250 pots.

COMMERCIAL CRAB HOUSE

Photo By: Jessica Lee

The total number of vessels landing blue crabs ranged from 1,077 in 2016 to 1,192 in 2009 (Table 13). Most vessels land 5,000 pounds or less of blue crabs. The number of vessels landing less than 1,000 pounds has remained stable since 2010, except for 2014 when the numbers peaked at 343. The number of vessels landing 1,000 to 5,000 pounds has fluctuated over the years, declined from 214 in 2015 to 201 in 2016. The number of vessels landing 5,001 to 10,000 pounds declined overall from 2007 to 2013, and then increased in 2014, and has remained stable since. Fluctuations in the number of vessels landing more than 20,000 pounds occurred over the time period. Looking specifically at the number of vessels landing more than 100,000 pounds, the number of vessels was lowest in 2007 at 33 and then increased to 94 in the following year. Since then, the number of vessels landing more than 100,000 pounds declined and remained in the 70s to 80s until 2013 at which point then declined. In 2015, the number of vessels with landings more than 100,000 pounds peaked at 102 and has declined since then.

Table 13 Annual number of vessels landing blue crab by poundage range, 2007-2016.

Year	< 1,000 Pounds	1,000 - 5,000 Pounds	5,001 - 10,000 Pounds	10,001 - 20,000 Pounds	20,001 - 50,000 Pounds	50,001 - 100,000 Pounds	>100,000 Pounds	Total
2007	317	216	131	124	181	107	33	1,109
2008	325	182	97	108	160	132	94	1,098
2009	337	213	122	122	198	128	72	1,192
2010	299	222	120	134	199	124	79	1,177
2011	306	179	108	136	194	109	82	1,114
2012	300	203	97	137	172	91	77	1,077
2013	309	204	108	136	152	89	57	1,055
2014	343	185	129	122	171	106	68	1,124
2015	307	214	125	142	167	98	102	1,155
2016	295	201	120	119	188	83	71	1,077
Average	314	202	116	128	178	107	74	1,118

Seafood Dealers and Shedders

The number of seafood dealers reporting landings of blue crabs has ranged from 241 in 2008 to 280 in 2010 (Table 14). Most dealers operate in the hard-shell crab fishery with the number of dealers reporting hard-shell crabs ranging from 211 in 2007 to 245 in 2010. The number of dealers reporting landings of peeler crabs ranged from 111 in 2016 to 124 in 2007. Looking at soft-shell crabs, the number of dealers reporting landings has ranged from 77 in 2015 to 102 in 2007.

Table 14 Annual number of seafood dealers reporting landings of blue crab, 2007-2016.

Year	Number of Dealers w/ Blue Crab Landings	Number of Dealers w/ Hard-Shell Crab Landings	Number of Dealers w/ Peeler Crab Landings	Number of Dealers w/ Soft-Shell Crab Landing
2007	247	211	124	102
2008	241	217	118	94
2009	274	243	123	94
2010	280	245	118	98
2011	266	230	120	88
2012	259	227	116	82
2013	243	213	113	86
2014	269	241	119	96
2015	252	223	116	77
2016	268	226	111	84
Average	260	228	118	90

The number of blue crab shedding permits issued by fiscal year ranged from 267 in 2013 to 314 in 2007 (Table 15). Shedding operations used mostly two types of tanks: closed recirculating or flow-through tanks. Two other types of tanks may also be used, but they are much less common (floating tank and other types). The number of flow-through tanks have generally declined from 2007 and ranged from 4,067 in 2013 to 4,067 in 2007. The number of close recirculation tanks have followed the same overall pattern through 2012 but showed an increase in 2013 to 2015 before declining again. The number of closed recirculating tanks ranged from 955 in 2012 to 1,665 in 2007.

Table 15 Annual number of permitted blue crab shedding operations, 2007-2016. Fiscal year runs from July 1 through June 30.

Fiscal Year	Shedding Permits Issued	Closed Recirculating Tanks	Flow Through Tanks	Floating Tanks	Other Tanks
2007	314	1,665	6,642	63	32
2008	304	1,564	6,462	339	31
2009	300	1,166	5,152	543	55
2010	301	1,046	5,941	238	71
2011	292	1,145	5,192	16	1
2012	287	955	5,534	74	13
2013	267	1,261	4,067	40	0
2014	279	1,378	4,224	144	31
2015	268	1,418	4,104	87	82
2016	268	1,312	4,265	146	74
Average	288	1,291	5,158	169	39

Crab Processors

Crab processing is an important component of the blue crab commercial industry. In North Carolina, crab processing facilities may have two types of permits. The first type is for the initial cooking, picking, and packing of crab meat. The second type is for repacking crab meat that has previously been cooked and packaged. An individual facility may have one or both types of permits which must be renewed annually and expire on March 31 each year. The number of permitted processing facilities has remained fairly stable since 2007 (Table 16). However, the number of permitted facilities is roughly half of what it was in the late 1990s (38). Several factors have contributed to the decline in the number of processing facilities including a shift from processed crabs to a live basket market, increased competition from imports, and more stringent federal Hazard Analysis and Critical Control Point (HACCP) requirements.

MEASURING COMMERCIALS CRAB CATCH

Photo By: Corrin Flora

Table 16 Annual (April 1-March 31) number of permits issued for crustacea processing facilities, 2007-2018. Data from the NCDMF Shellfish Sanitation section.

Year	Total Number of Permitted Facilities	Total Number of Picking Permits	Total Number of Repacking Permits	Total Number of Facilities Permitted for Picking and Repacking
2007-2008	10	7	2	1
2008-2009	9	6	2	1
2009-2010	13	7	2	4
2010-2011	11	5	2	3
2011-2012	14	8	3	3
2012-2013	13	8	2	3
2013-2014	11	7	1	3
2014-2015	11	7	1	3
2015-2016	17	8	2	7
2016-2017	17	6	2	9
2017-2018	14	4	2	8
2018-2019	15	4	2	9

Swimming Crab Imports

The United States imports two types of "swimming crabs" related to blue crab: Portunidae (the family that includes blue crabs) and Callinectes (the blue crab genus). According to NOAA Fisheries U.S. Foreign Trade database, total U.S. imports of swimming crab have averaged 46.8 million pounds and $384 million per year between 2007 and 2016. Imports bearing the broader Portunidae label averaged 39.8 percent of the total volume and 36.6 percent of the total real value of swimming crab imports during the period. Imports under the Callinectes label averaged 60.2 percent of total volume and 63.4 percent of the total real value of swimming crab imports from 2007 to 2016. The United States imports swimming crab in two forms, frozen and in airtight containers. Imports of frozen crab averaged 4.1 million pounds and $23.6 million per year from 2007 to 2016; imports of crab in airtight containers averaged 42.7 million pounds and $360 million per year during the same period.

Between 2007 and 2016, the United States imported swimming crab products from as few as 14 to as many as 21 different countries. The majority of swimming crab products come from a relatively small number of countries with five countries making up an average of 80% of imports from 2007 to 2016. Indonesia has been the number one source of swimming crab product imports in every year from 2007 to 2016. The total volume of swimming crab product imports from Indonesia comprised almost one-third of the total volume of all swimming crab product imports on average from 2007 to 2016 (42).

Summary of Economic Impact of Commercial Fishing

The economic impact estimates presented represent those of commercial blue crab harvesters, dealers, and processors and are calculated via the NCDMF commercial fishing economic impact model. These estimates are given for four categories: all commercial blue crab harvest, hard blue crab harvest, peeler blue crab harvest, and soft blue crab harvest.

Blue crab boasts the highest ex-vessel values in the state and 2016 resulted in over $150 million in economic impact (Table 17), with hard blue crabs dominating this cash flow. Peeler and soft blue crabs also contribute to this industry, each generally producing greater than $1 million in ex-vessel revenues per year. On top of this, the peeler and soft blue crab fisheries tend to exhibit similar landings values, with soft blue crab values slightly higher overall. Additionally, annual changes in ex-vessel value across segments are generally consistent, in that years with lower hard blue crab revenues tend to exhibit lower soft and peeler blue crab revenues as well (Tables 18, 19, and 20).

Given gear and catch changes are proposed under this amendment, the commercial fishery will likely see a reduction in ex-vessel value due to an expected reduction in landings. However, effort, and therefore supply, are not being controlled for, and because of this, expected changes to marginal prices of crab are unknown. Additionally, as management changes that reduce landings are being implemented across all aspects of the blue crab fishery, economic losses due to these regulations can be expected across the hard, soft, and peeler fisheries. Lastly, these output measures were calculated using annual ex-vessel values and participant counts. While ex-vessel values per blue crab segment are fully independent, some participants may be fishing across multiple segments, possibly even during the same trip. Because of this, output measures on a per-segment scale (Tables 18, 19, and 20) are not additive and may be over-estimating total contributions, but still capture the socioeconomic importance of each blue crab fishery to the state economy.

Table 17 Economic impacts associated with the commercial blue crab fishery for all product categories, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	884	25,459,475	24,112,715	2,313	56,569,819	85,443,052	123,871,511
2008	923	32,134,501	33,724,424	2,782	68,330,127	103,098,756	155,900,595
2009	923	26,230,965	34,027,403	2,807	69,978,824	105,642,579	155,668,594
2010	863	22,202,623	30,006,447	2,656	65,839,269	99,304,559	149,381,907
2011	895	26,785,669	22,806,938	2,069	51,868,420	78,192,850	119,032,842
2012	925	30,035,392	21,282,264	2,217	56,147,717	84,607,194	128,240,957
2013	984	30,683,011	26,543,791	2,882	72,762,337	109,704,172	167,489,172
2014	990	29,707,232	27,428,995	3,255	83,092,013	125,316,017	190,518,399
2015	914	32,916,691	27,555,386	3,329	84,243,536	127,096,494	190,345,529
2016	952	21,424,960	21,431,955	2,302	61,024,899	91,970,507	151,757,244

[1] As reported by the North Carolina Trip Ticket Program

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

[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.

[4] Represents sales impacts

Table 18 Economic impacts associated with the commercial blue crab fishery for hard blue crabs only, 2007 -2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	862	24,728,862	20,734,833	2,142	54,520,426	82,794,003	119,109,877
2008	883	31,047,438	29,457,925	2,674	67,018,157	101,401,623	152,852,403
2009	887	25,242,648	29,954,605	2,689	68,542,255	103,783,999	152,327,477
2010	815	21,438,077	26,465,523	2,520	64,179,463	97,157,235	145,519,395
2011	837	25,991,387	20,198,891	1,908	49,882,882	75,624,156	114,416,771
2012	883	28,964,633	18,016,736	2,087	54,544,208	82,532,792	124,514,063
2013	944	29,794,329	23,801,594	2,704	70,621,095	106,934,054	162,511,562
2014	943	29,140,473	25,039,379	3,051	80,629,140	122,129,805	184,793,115
2015	857	32,338,889	25,429,231	3,115	81,663,530	123,758,747	184,347,951
2016	890	20,562,159	18,109,497	2,142	58,906,380	89,230,343	144,809,891

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

Table 19 Economic impacts associated with the commercial blue crab fishery for peeler blue crabs only, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	476	445,844	1,314,879	1,272	44,081,515	69,300,649	94,855,735
2008	534	706,688	2,111,103	1,430	51,871,181	81,807,854	117,660,362
2009	534	621,040	1,935,462	1,512	54,154,728	85,169,934	118,865,501
2010	502	447,120	1,449,542	1,392	50,497,796	79,456,993	113,680,978
2011	506	468,855	1,112,025	1,075	39,649,466	62,385,167	90,625,651
2012	511	624,362	1,186,286	1,139	42,808,999	67,351,373	97,238,954
2013	551	568,210	1,197,855	1,449	55,493,614	87,363,675	127,345,662
2014	561	367,881	1,106,883	1,646	63,685,607	100,210,007	145,405,556
2015	526	351,986	882,319	1,743	65,126,559	102,364,916	145,905,501
2016	548	498,904	1,186,031	1,224	46,726,694	73,476,730	104,868,510

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

Table 20 Economic impacts associated with the commercial blue crab fishery for soft blue crabs only, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	237	284,769	2,063,004	1,321	44,667,748	70,058,414	96,217,809
2008	241	380,375	2,155,396	1,449	52,094,259	82,096,423	118,178,657
2009	259	367,277	2,137,335	1,521	54,260,444	85,306,706	119,111,372
2010	253	317,426	2,091,382	1,410	50,707,520	79,728,316	114,169,022
2011	229	325,426	1,496,021	1,119	40,192,410	63,087,575	91,887,913
2012	209	446,397	2,079,242	1,158	43,045,092	67,656,799	97,787,685
2013	238	320,472	1,544,342	1,482	55,881,742	87,865,796	128,247,920
2014	245	198,878	1,282,733	1,656	63,807,683	100,367,936	145,689,337
2015	245	225,816	1,243,836	1,745	65,153,344	102,399,567	145,967,765
2016	270	363,896	2,136,426	1,259	47,195,899	74,083,615	106,407,193

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

RECREATIONAL FISHERY

Recreational Harvest Estimates

Recreational fishermen harvest blue crab for personal consumption and use as bait. Harvest occurs using a variety of gears including crab pots (rigid and collapsible), gill nets, shrimp trawls, trot-lines, hand-lines, and dip nets. Prior to July 1999, no license was required to harvest blue crab recreationally unless a vessel was used. Since July 1, 1999, a RCGL has been required to recreationally harvest blue crab using commercial gear. Gears exempt from this license include collapsible crab pots, cast nets, dip nets, hand-lines, and seines (less than 30 feet). Additionally, one pot per person may be fished from shore along privately-owned land or a privately-owned pier without a RCGL. The recreational harvest limit for blue crab is 50 per person per day, not to exceed 100 per vessel. A Coastal Recreational Fishing License (CRFL) is not required to recreationally harvest blue crabs.

Long-term comprehensive estimates of recreational harvest data are lacking in North Carolina. However, there have been several short-term, or targeted surveys, meant to estimate recreational blue crab harvest. In 2002, Vogelsong et al. (43) surveyed coastal waterfront landowners to estimate recreational harvest. They found that approximately 30% harvested blue crab from their property and 7% harvest blue crab away from their property. It was estimated that 279,434 pounds of blue crabs were harvested in 2002 by coastal waterfront landowners. From 2002 to 2008, the NCDMF surveyed RCGL holders and estimated an average of 587,172 pounds were harvested annually. In the fall of 2010, the NCDMF began surveying CRFL holders that indicated they harvested crabs. From 2011 to 2016, an estimated average of 97,774 blue crabs (approximately 32,591 pounds) was harvested annually.

Summary of Economic Impact of Recreational Fishing

The economic impact estimates presented for blue crab recreational fishing represent the economic activity generated from trip expenditures. It should be noted that not included in these estimates, but often presented in NCDMF overall recreational impacts models, are the durable good impacts from economic activity associated with the consumption of durable goods (e.g., rods and reels, other fishing-related equipment, boats, vehicles, and second homes).

Overall, the economic impact of blue crab harvesting is significantly smaller than the commercial impact, with an estimated economic impact of $2.7 million in 2016 (Table 21). This is reflective of the lack of a sport fishery, as well as its importance to the commercial seafood trade. The majority of recreational blue crab trips occur onshore (not requiring a vessel), and therefore often provide fewer market-level benefits, with the only inputs being gear and bait purchases, travel to site, and permitting. Of those trips that occur in a vessel, these occur near or inshore and require less gear, fuel, and other related expenditures.

BLUE CRAB UNDER WATER

Photo By: NCDMF staff

With the proposed management changes, there will be little effect felt on the recreational fishery from an economic standpoint. Moving forward, there may be economic gains in the recreational sector, as the proposed changes may improve abundance over time, leading to better access and interest for recreational blue crab harvest.

Table 21 Economic impacts associated with recreational blue crab fishing, 2010-2016.

Year	Trips[1]	Estimated Expenditures (thousands of dollars)[2]	Jobs[3,4]	Income Impacts (thousands of dollars)[4]	Value-Added Impacts (thousands of dollars)[4]	Output Impacts (thousands of dollars)[4]
2010	5173	719,703	7	204,531	318,772	564,174
2011	24818	3,595,514	33	1,007,600	1,566,718	2,769,964
2012	26863	3,969,593	36	1,109,089	1,724,489	3,052,227
2013	30732	4,698,622	41	1,275,287	1,973,401	3,497,781
2014	23381	3,583,168	31	992,335	1,538,414	2,732,729
2015	27963	4,289,639	37	1,176,955	1,822,986	3,255,294
2016	23325	3,629,892	31	1,001,615	1,550,695	2,748,555

[1] Trip estimates from Coastal Recreational Fishing License (CRFL) surveys

[2] Estimated expenditures include only trip expenditures.

[3] Includes full time and part time jobs

[4] Economic impacts calculated using the NCDMF coastal recreational fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.

FISHERY IMPACT ON THE ECOSYSTEM

HABITAT

Bottom disturbing fishing gear can impact ecosystem function through habitat degradation, bycatch, and derelict gear. The primary gear used in the blue crab fishery is crab pots, although crab trawls and crab dredges are also used and make up a small portion of the fishery. Other gears used include trot-lines, hand-lines, and dip nets, but ecosystem impacts are considered minimal due to the construction of the gear and fishing methods.

GEAR IMPACTS TO HABITAT

FOOTPRINT OF DERELICT POT IN SAV BED

Photo Credit: NOAA

While crab pots are the most abundant gear used in the fishery, their impact on habitat (on an individual pot basis) is relatively low due to their small footprint, lightweight, open structure, and location placed. Physical impacts increase if pots are placed directly on structured habitat for prolonged periods. A study conducted in North Carolina found that prolonged deployment or movement of crab pots on marsh vegetation, which can occur when gear is lost or abandoned, significantly reduced stem height and density after being present eight weeks (44). The cumulative loss of wetlands could degrade the ecosystem services they provide, such as nursery habitat, pollutant removal, and shoreline stabilization (45). Fortunately, Uhrin and Schellinger (44) found that when pots were removed, the vegetation recovered after approximately four months. In contrast, damage to submerged aquatic vegetation (SAV) from derelict pots is potentially greater and more permanent due to sedimentation in the pot, scour around the edges, and additional uprooting of grass along a path if dragged across the bottom during storms (46; 47; 48). Submerged aquatic vegetation is an important fish habitat consisting of underwater rooted vascular plants and is defined in rule [NCMFC Rule 15A NCAC 03I .0101 (4)(i)]. The extent that pots are interacting with and damaging SAV beds in NC is not known. Where resources are limited, derelict gear cleanup should prioritize the removal of pots on or near SAV (44). Zinc plates used to minimize rusting on crab pots are a habitat concern since these may contribute to heavy metal pollution in estuarine systems (49). Research is needed to validate this potential impact.

With an estimate of over one million crab pots deployed annually in North Carolina (38), crab pots are potentially impeding ecological function of soft bottom habitat as a migratory corridor. Inlets, a type of soft bottom, are a critical bottleneck for mature females as they move through the lower estuary to spawning areas. The five most northerly inlets in North Carolina are designated as Crab Spawning Sanctuaries, with seasonal gear restrictions to aid migration and spawning. The remaining 16 inlets do not have similar protection. The protective effectiveness of the existing sanctuaries and associated rules continues to be a research need. Eggleston et al. (50) found female blue crab abundance to be no different inside the crab spawning sanctuaries than 1 km to 2 km outside the boundaries. Modification of Crab Spawning Sanctuary boundaries or rules could potentially improve their effectiveness.

Crab trawls and crab dredges are mobile bottom-disturbing fishing gear. Reviews of fishing gear impacts have categorized crab dredging and crab/shrimp trawling as having severe and moderate impacts to SAV, respectively (49; 51; 46; 45). Crab dredging is particularly damaging due to the long teeth that are designed to dig deep into the sediment, uprooting and destroying above and below-ground plant structure. Crab trawls can also cause extensive damage to SAV from trawl doors that dig into the sediment and uproot plants. Dragged chain can cut or damage above-ground leaves, but this does not always result in complete mortality (46). Both dredges and trawls can elevate turbidity, reducing water clarity needed for SAV growth and survival. Loss and damage to SAV is detrimental to the estuarine system due to the large diversity of fish and invertebrates that are dependent on it as a nursery and foraging area (45). Over 34 economically important fish species, and 150 other fish and invertebrates, have been documented in SAV in North Carolina. Additionally, SAV improves water clarity, cycles nutrients, and sequesters carbon. More information on the ecological value, distribution, and condition of SAV in North Carolina can be found in the Coastal Habitat Protection Plan (45).

OYSTER REEF

Photo By: Chesapeake Bay Foundation

Crab trawling and crab dredging can cause structural damage to oyster reefs (52). Dredging reduces the height of subtidal reefs, scatters and removes shell substrate needed for oyster recruitment, and destabilizes the reef structure (53; 54). Subsequently, substrate available for oyster recruitment and structural habitat complexity for refuge and foraging are reduced. The lower profile of the disturbed shell bottom is more susceptible to sedimentation, disease, and hypoxia. Structurally complex oyster reefs are critical habitat for blue crab, as well as over 40 economically important species, and numerous prey species. Oyster reefs improve water quality, stabilize bottom sediment, and reduce shoreline erosion (45). It is estimated that over 90% of subtidal oyster reefs have been lost since the late 1800s. Historical and more recent losses of oyster reefs in the Pamlico Sound region are summarized in NCDMF (52) and NCDEQ (45). Historical losses are attributed primarily to overharvesting from oyster dredging and have not recovered due to disease, water quality issues, and lack of hard substrate for recruitment. Significant resources are being invested in oyster restoration, so any fishery activity that impacts shell bottom would be counterproductive to those efforts.

Because of the documented impacts to SAV and shell bottom, dredging and trawling are primarily restricted to soft-bottom habitat. While soft-bottom habitat is more dynamic and adapted to disturbance, productivity can still be impacted. Dragging gear over the bottom reduces small scale habitat complexity of soft-bottom structure by removing or damaging scattered epifauna such as sponges, removing benthic invertebrates that produce burrows and pits such as tube worms, and smoothing of features such as sediment ridges and ripples (55; 51). Reduced structural complexity and increased turbidity from frequent trawling can reduce feeding success of filter-feeding invertebrates due to gill clogging or can increase predation by exposing organisms previously buried and reducing cover (55). In a review of gear impacts by Johnson (13), toothed dredging activities in soft-bottom habitat appear to have a significant physical impact on the benthic organisms and topography in the dredge path, but there were few long-term impacts. Most studies reported the recovery of taxa and topography in three to six months. Impacts from crab trawling are similar or somewhat more severe to those reported for shrimp trawling since crab trawls use heavier chain and doors that can dig deeper into the sediment.

Studies that have examined the effects of crab and shrimp trawling on turbidity and productivity of shallow estuarine soft-bottom habitat have shown little sustained negative or positive impacts on primary or secondary productivity. Suspended sediment significantly increased in the water column up to three times greater than pre-trawling conditions but redeposited at varying rates, depending on the substrate and currents (56; 57; 58). Sedimentation in North Carolina studies varied between 15 minutes and 24 hours, occurring faster in areas with sandy sediment, low currents, and calm winds. Studies on the effects of trawling on primary production found mixed results, with benthic microalgae reduced in one study but not others (59; 57; 60). One explanation for low impacts from gear disturbance is the bottom in North Carolina's shallow estuarine system is frequently disturbed by wind and consequently, the benthic community is adapted to bottom disturbance.

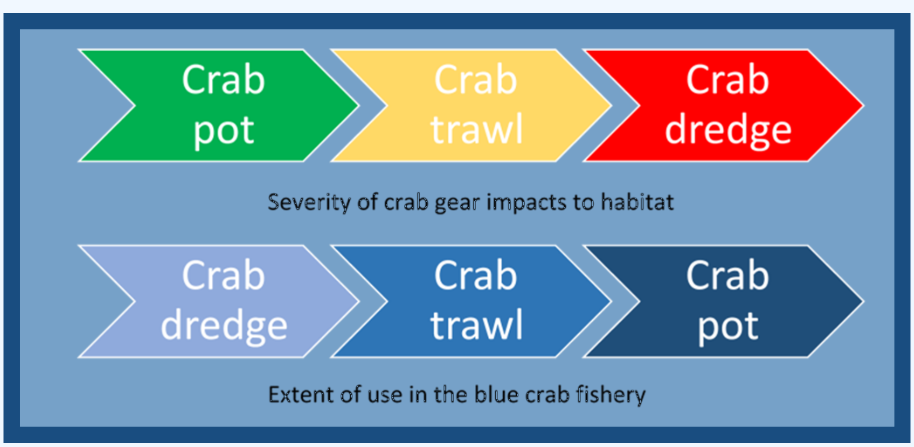
OYSTER REEF

Photo By: NCDMF Oyster Sanctuary Program

CRABBING IN CORE SOUND

Photo by: NCDMF staff

Habitat impacts from crab dredging and trawling are limited by the relatively low amount of fishing effort with these gears. From 2014 to 2016, the number of crab trawl trips ranged from 180 to 470 per year, and the number of crab dredge trips ranged from 3 to 14 per year. In contrast, there were 4,598-7,468 shrimp trawl trips during this same period. Crab dredge use is limited to an area of primarily soft-bottom habitat in northern Pamlico Sound (approximately 86,900 acres) and is opened by rule from January 1 to March 1 [NCMFC Rule15A NCAC 3L .0203]. Some SAV and subtidal shell bottom may also occur in or near this area. Although the low fishing effort results in a small area of impact due to crab dredging, the destructive potential of the gear to all habitats, combined with spatial preference for harvesting mature female blue crabs, results in a net adverse impact to blue crabs from the use of this gear. Crab trawl use occurs in areas open to trawling predominantly in Pamlico Sound and adjacent estuarine rivers. There is potential for crab trawling to occur over SAV in the western portions of the Pamlico system, although most SAV occurs in water less than 1 m, where it is too shallow for trawl operation. There is also potential for crab trawling to occur over or near low profile oyster bottom, potentially damaging the integrity of the habitat and increasing turbidity.



BYCATCH AND DISCARDS

Undersized and Other Non-Legal Blue Crabs

As of June 2016, through the revision to Amendment 2, hard crabs must measure five inches from point to point on the carapace for males or be in the mature stage for females to be considered legal for harvest. Additionally, mature females possessing a dark sponge (brown and black stages) may not be kept between April 1 and April 30 each year. A culling tolerance allows no more than five percent by number of any combination of undersize males, and immature or dark sponge bearing females to be possessed. Any hard blue crab not considered legal for harvest must be immediately returned to the water from where they were taken. Crab pots may attract and capture blue crabs which are not legal for harvest and their chance of becoming injured and dying increases the longer they are trapped (61).

CRAB POT CLEANUP

Photo By: Chris Hannant Photography

Cull (escape) rings can be mounted to crab pots to help undersized crabs escape while retaining legal-sized catch. Both the location and size of the cull rings can affect the odds of undersized crabs escaping (62; 63). As of January 2017, implemented by the revision to Amendment 2, both commercial and recreational hard crab pots in North Carolina are required to have three escape rings with an inside diameter no smaller than two and five-sixteenths inches. Two of these escape rings must be mounted on opposite outside panels, and one must be mounted in a corner close to the bottom of the pot, or upper chamber if present. These requirements apply statewide, except NCMFC Rule 15A NCAC 03J .0301(g) allows for specific areas in Pamlico Sound and the Newport River as exceptions in NCMFC rule (15A NCAC 03R .0118) and are intended to reduce the capture and mortality of undersized hard crabs.

Other Species

Crab pots are the predominant gear in the blue crab fishery, with crab trawls and crab dredges making up a very small percentage of the total gear used. Both finfish and shellfish species may be caught as bycatch in crab pots. This bycatch may be retained and landed as incidental catch or discarded as a result of economic, legal, or personal considerations.

Statewide annual landings of the marketable portion of the incidental bycatch from hard crab and peeler pots, as recorded by the NCDMF Trip Ticket Program single gear trips, has averaged 57,343 pounds since 2007 and represents 0.02% of the total landings from this gear. Seven species or species groups comprise over 90% of all incidental catch landed from hard crab and peeler pots: catfish 36% (*Ictaluridae spp.*), oyster toadfish 19% (*Opsanus tau*), whelks 18% (*Busycon spp., Busycotypus spp.*), Florida stone crabs 10% (*Menippe mercenaria*), southern flounder 5% (*Paralichthys lethostigma*), northern puffer 2% (*Sphoeroides maculatus*), and spotted seatrout 2% (*Cynoscion nebulosus*) (Figure 7).

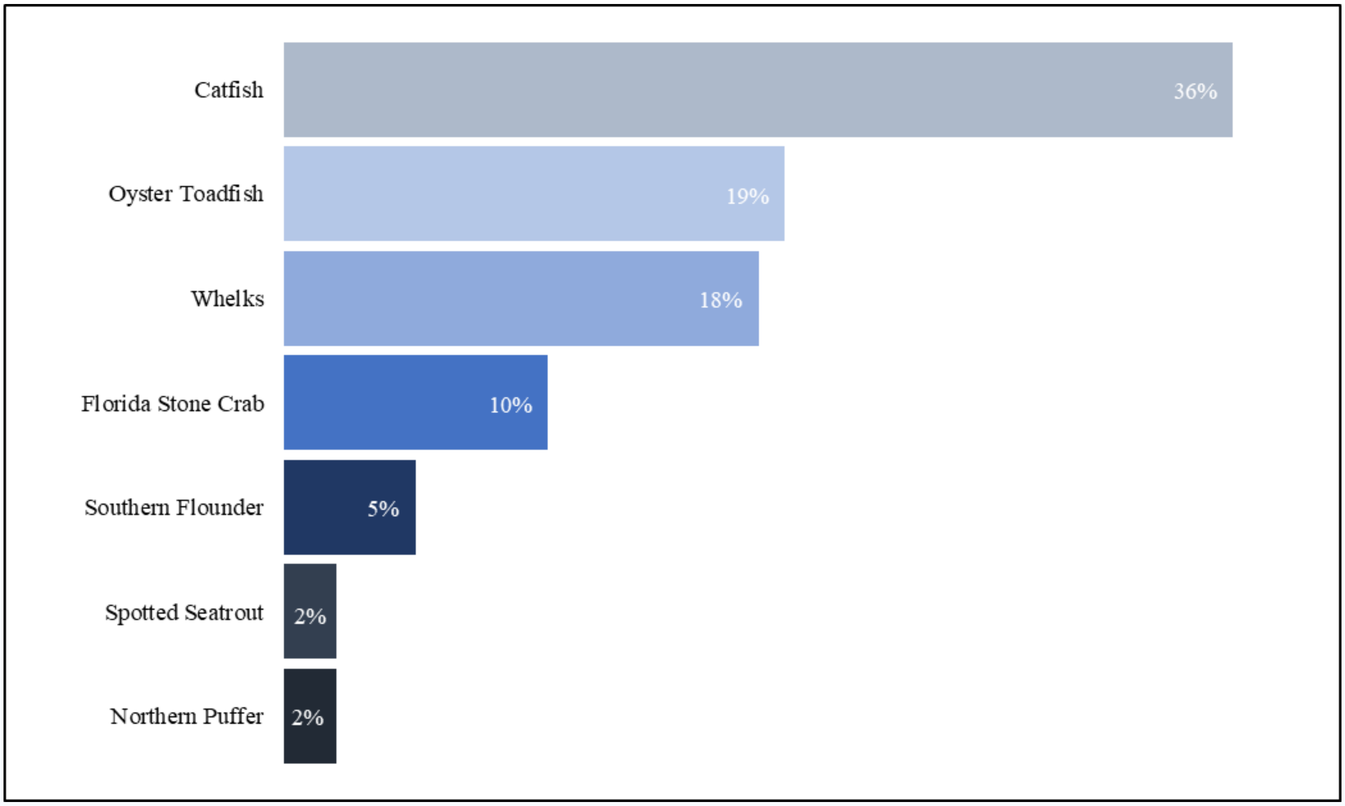


Figure 7 The percentage each of the top seven species (or species groups) contributes to all incidental catch landed from hard crab and peeler pots between 2007 and 2016.

Bycatch and discards have been examined in the North Carolina blue crab pot fishery. Doxey (64) examined bycatch in both hard crab and peeler pots in the Neuse River. Flounder (*Paralichthys spp*.) accounted for 34% of the total hard crab pot bycatch, and other important species reported captured in this study include spot (*Leiostomus xanthurus*), spotted seatrout, gray trout (*Cynoscion regalis*), red drum (*Sciaenops ocellatus*), and diamondback terrapin (*Malaclemys terrapin*). The catch-per-unit-effort of all bycatch species averaged 0.007 organisms per hard crab pot, and of the captured bycatch in hard crab pots, 70% were released alive, 22% were either dead or injured, and 8% was used for bait. Thorpe et al. (65), investigated bycatch in hard crab pots in locations in Brunswick and Carteret Counties. Sub legal southern flounder were the most commercially and recreationally important fish species caught as bycatch in this study, with other finfish bycatch including, spadefish (*Chaetodipterus faber*), oyster toadfish, and pinfish (*Lagodon rhomboides*). Other species captured included diamondback terrapins, as well as channeled whelk (*Busycotypus canaliculatus*) and Florida stone crabs, which are two important shellfish species caught as bycatch and landed as incidental catch during this research.

NCDMF (10) evaluated the ability of multiple finfish species to escape both control crab pots (without escapement “cull” openings) and crab pots with escapement openings, over 24 hours. White catfish (*Ameiurus catus*), black drum (*Pogonias cromis*), and white perch (*Morone Americana*) had the highest escapement rates, and southern flounder had the lowest rate. Overall escapement from the control pots was very good and increasing the size of the escapement openings appeared to enhance escapement efficiency for finfish species.

Protected Species

Protected species is a broad term that encompasses a range of organisms identified by federal or state protective statutes, such as the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and Migratory Bird Treaty Act. Of the many federal and state protected species, whales, bottlenose dolphins, sea turtles, and diamondback terrapins are considered to have the greatest potential to interact with the North Carolina blue crab fishery. Baited crab pots may attract protected species that can get entangled in the buoy lines or entrapped. Although crab trawls are an active gear that focus on the estuarine bottom and are restricted to areas without submerged aquatic vegetation, interactions with protected species are possible. Crab dredges are an active bottom gear restricted to a small, specific area of Pamlico Sound and therefore are less likely to interact with protected species than the other two gears mentioned.

Since the 1970s, the NCDMF has been proactive in developing ways to minimize impacts to threatened and endangered marine species. The NCDMF works closely with the National Oceanic and Atmospheric Administration (NOAA) Fisheries and other state and federal agencies to develop regulations that minimize impacts to protected species and still allow for economically important fisheries.

Marine Mammals

North Carolina has two species of baleen whales that traverse the state during their annual migration. These are the North Atlantic right whale (*Eubalaena glacialis*) and the humpback whale (*Megaptera novaeangliae*), both of which are protected under the MMPA and have been designated endangered under the ESA. Ship strikes pose a threat to many baleen whales, particularly the critically endangered North Atlantic right whale. Entanglement in various types of fishing gear is an additional threat to many species of whales. The humpback is one of the most abundant whale species off the North Carolina coast and one of the most often affected in entanglements in this state (38).

BLUE CRABS

Photo By: Jeff Dobbs

Bottlenose dolphins (*Tursiops truncatus*) are occasionally captured or entangled in various kinds of fishing gear. Bottlenose dolphin carcasses that displayed evidence of possible interaction with a trap/pot fishery (i.e., rope and/or pots attached, or rope marks) have been recovered by the Marine Mammal Stranding Network between North Carolina and the Atlantic coast of Florida (38).

The North Carolina blue crab fishery has been categorized as a level II commercial fishery by the federal government in regard to the MMPA, or as only having occasional interactions with marine mammals (66). Most of the crab pot effort in the North Carolina blue crab fishery is located within the sounds, rivers, and estuaries of the state, with a very small portion occurring in the nearshore coastal ocean. As a protection for marine mammals in North Carolina ocean waters, fishermen setting any type of pots in nearshore waters (inside the 100-foot contour) are required to use sinking lines and break-away devices known as “weak links”. Weak links in this nearshore area off North Carolina must have a breaking strength no greater than 600 lbs., while beyond the 100-foot contour to the eastern edge of the Exclusive Economic Zone (EEZ), a breaking strength of no greater than 1,500 lbs. is required (67). In state inshore waters, NCMFC Rule 15A NCAC 03J .0301 (k) makes it unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating to reduce interactions with boaters, which also reduces the potential for marine mammal entanglements in this gear.

Sea Turtles


GREEN SEA TURTLE

Photo By: Jeff Dobbs

Five species of sea turtles occur in North Carolina, Kemp's ridley sea turtle (*Lepidochelys kempii*), hawksbill sea turtle (*Eretmochelys imbricate*), leatherback sea turtle (*Dermochelys coriacea*), green sea turtle (*Chelonia mydas*), and the loggerhead sea turtle (*Caretta caretta*). Loggerhead and green sea turtles are federally listed as threatened, while the others are listed as endangered.

Sea turtles may be attracted to baited crab pots as a source of food. Sea turtle entrapment in a pot or trap is not likely, but entanglement in the buoy lines of pots has been documented (68). There have been documented cases of loggerhead sea turtles entangled in crab pot gear in North Carolina, which lead to the death of the turtle (38). As sea turtles attempt to obtain either bait or crabs from crab pots, significant damage to the gear can occur. Sea turtles reportedly overturn the pot and bite the bottoms and sides, resulting in torn mesh and crushed pots. This damage also results in higher operating costs and decreased catches for crabbers. Plastic bait well covers have been shown to significantly reduce pot damage from loggerhead turtles and result in higher average blue crab catch when used on typical crab pots (69).

Diamondback Terrapins

Diamondback terrapins are a relatively small turtle species found throughout North Carolina's estuarine coastal waters. This species is listed by the North Carolina Wildlife Resources Commission (NCWRC) as a North Carolina species of "Special Concern" statewide and as a Federal "Species of Concern" in Dare, Pamlico, and Carteret counties in NC. However, these designations do not specifically provide any special state or federal protection.

Populations of diamondback terrapins have declined throughout their range and their incidental capture in crab pots may account for more adult diamondback terrapin mortalities than any other single factor (70). Diamondback terrapins are long-lived, late to mature, and display relatively low fecundity (71). Delayed sexual maturity and low reproductive rates, coupled with long life spans and strong site fidelity, are characteristics that make this species especially susceptible to substantial population declines or even local extinction from incidental bycatch and death of a relatively low number of individuals from the population annually (72; 73).


JUVENILE DIAMONDBACK TERRAPINS

Photo By: NCDEQ

Several factors have been identified in determining the likelihood of diamondback terrapin bycatch in crab pots where crab fishing activities and diamondback terrapin occurrence overlap, and considering these factors, diamondback terrapin mortality from incidental bycatch in crab pots can be mitigated in North Carolina. Each of these limiting factors and its relationship to diamondback terrapin catchability in crab pots, as well as establishing a framework to employ terrapin excluder devices in the blue crab fishery is discussed in the issue paper: Appendix 4.5: Establish a Framework to Implement the Use of Terrapin Excluder Devices in Crab Pots.

Derelict Gear

Derelict gear or "ghost pots" are crab pots that either through abandonment or loss (buoy lines cut by boats, storm events, etc.) continue to catch crabs and finfish. The long life of vinyl-coated crab pots, and their ability to continue to capture blue crabs and finfish, raises concern about their impact on the ecosystem if they are lost or abandoned.

The number of crab pots used in the North Carolina commercial blue crab fishery is considered to be over one million, with an annual hard crab pot loss estimate of 17% (38). A ghost pot study conducted by NCDMF estimated the average yearly catch of legal blue crabs in a single ghost pot to be 40.4 individuals, with an average mortality rate of 45% (10). Voss et al. (74) conducted a study examining derelict crab pots in North Carolina and found that 41% of retrieved pots contained bycatch, 37% were capable of trapping organisms, and the pots retrieved were estimated to have been in the water for an average of approximately 2 years. In that study, a total of 18 species were identified as unable to leave the pot and likely to suffer mortality. The most abundant of these species, which are also of management interest to NCDMF, included: blue crab, Florida stone crab, sheepshead (*Archosargus probatocephalus*), black sea bass (*Centropristis striata*), and diamondback terrapin.

Since 2003, the NCDMF Marine Patrol has been actively removing derelict crab pots from state waters during the winter clean up period. Between January 15 and February 7 each year, all pots are required to be removed from the water. Any crab pots found during this time are considered lost or abandoned and removed from our waterways. The NC Coastal Federation began a pilot study in 2013 to employ commercial fishermen to collect derelict crab pots in the northern region of the state. In 2017 this cooperative cleanup effort was expanded statewide, resulting in over 35,000 ghost pots being removed from North Carolina waters by the NCDMF Marine Patrol and commercial waterman over the last fourteen years (Table 22).

Table 22 Number of derelict crab pots removed each year during the crab pot cleanup period between January 15 and February 7. The northern area is approximately from the Virginia state line to Ocracoke, the central area is from the Pungo River to Emerald Isle, and the southern area is from Cape Carteret to the South Carolina State line.

Year	Northern Area	Central Area	Southern Area	Total
2003	4,047	900	127	5,074
2004	7,708	527	108	8,343
2005	2,168	N/A	N/A	2,168
2006	1,117	391	24	1,532
2007	896	135	24	1,055
2008	757	190	110	1,057
2009	589	257	60	906
2010	570	154	24	748
2011	656	183	141	980
2012	684	160	295	1,139
2013	451	445	545	1,441
2014	364	64	226	654
2015	1,004	149	155	1,308
2016	753	80	70	903
2017	2,836	1,219	249	4,304
2018	2,245	1,004	247	3,496

ECOSYSTEM IMPACTS ON THE FISHERY

As previously described in the biological profile section, blue crabs migrate throughout the estuary and nearshore ocean, utilizing a variety of habitats along the way. Submerged aquatic vegetation (SAV), wetlands, and shell bottom are particularly important for refuge and foraging. Inlets are a critical area of soft-bottom for life cycle completion since planktonic megalopae must pass through the inlets to settle into estuarine nursery habitat, and conversely, sponge crabs must move to the inlet system and nearshore ocean to spawn. Since blue crabs depend on multiple habitats throughout the coastal system, degradation of any single habitat, as well as disruption of migratory connectivity, could negatively affect growth and survival of blue crabs. However, the high mobility of blue crabs within the system provides overall resilience to degradation in any one localized area.

WATER QUALITY DEGRADATION

Growth and survival of blue crabs are maximized when water quality parameters, such as temperature, salinity, and oxygen, are within optimal ranges. These parameters have been identified by life stage in the biological profile and other documents [Table 23; (75; 76; 45)]. When conditions are outside the suitable range for extended periods, blue crabs can be adversely impacted. Rapid changes in environmental parameters, typically associated with large freshwater influx from rain events or hurricanes, triggers blue crab movement and can temporarily alter the spatial distribution of blue crabs on a large scale (77; 78).

Table 23 Water quality parameters required by and habitats associated with different life stages of blue crab. No documented data where blank (75; 79; 76; 80).

Life Stage	Salinity (ppt)	Temperature (C)	DO (mg/L)	Associated Habitats
Adult	0-30	5-39	>3	Entire estuary
Spawning Female	23-28	19-29		Inlet and Ocean
Larvae	>20	16-30		Inlet and Ocean
Juveniles	2-21	16-30		Wetlands, SAV, Shell Bottom, Soft Bottom

Hypoxia

Low dissolved oxygen (hypoxia) can cause sublethal stress or mortality in blue crabs. Sublethal stress may alter feeding and growth rates, behavior, and vulnerability to predators (76). Where blue crabs could not escape hypoxic waters, mortality occurred when oxygen levels were below 3.0 mg/L for one to three days; mortality occurred within three hours when less than 0.5 mg/L (75). While adults require 3-5 mg/L DO, juvenile blue crabs may be less tolerant of hypoxia than adults (81) and may require more than 5 mg/L. Blue crab tolerance to hypoxia decreases with increasing temperature (82). A study showed blue crabs collected from the Neuse River Estuary, where frequent hypoxia occurs, had a hypoxia-tolerant structure and survived longer exposures to hypoxia than those collected from waters without this issue (Bogue and Back Sounds; (83).

Hypoxic events have resulted in locally elevated mortality among crabs constrained by capture in pots in the Chowan, Neuse, and Pamlico river systems ((84); T. Pratt, personal communications). Neuse River crab fishermen indicated they would move pots and alter fishing frequency during low oxygen events to avoid blue crabs dying in pots. Adjustments in fishing activity were based on changing environmental observations and catch rates (85). Low oxygen events occur naturally when the water column becomes stratified for a long period, particularly during summer in deeper areas. High nutrient levels and low flushing increase a waterbody's susceptibility to hypoxia and subsequent fish kills (45). Most nutrient pollution in the Albemarle-Pamlico system has been linked to agriculture (86; 87; 88). Other sources of nutrients are stormwater runoff from developed land and point source discharges of treated wastewater. Runoff transports nutrients, sediment, toxins, and pathogens into surface waters, and can lead to rapid changes in salinity and temperature (89; 45).

Indicators of hypoxic and anoxic water include: crabs swimming at or near the water's surface; crabs crawling out of the water on to shore; pot caught crabs clinging to the top of crab pots attempting to get out of the low oxygen water; weak crabs and reduced catches in pots; total mortality of potted crabs; and pots previously covered with aquatic organisms (marine fouling) suddenly appear clean.

Toxins

Chemical contaminants in the water and soft bottom can adversely impact blue crabs directly by causing mortality, or indirectly by altering endocrine related growth and reproductive processes. Acute toxicity of a variety of pesticides to blue crab was determined by the US Environmental Protection Agency and summarized in Funderburk et al. (75) and Osterberg et al. (90). These studies stated the presence of any pesticide had a detrimental effect and increased mortality rates on larval and juvenile blue crabs, particularly after molting. Many factors affect a chemical's toxicity to marine organisms. Eggs and larvae are generally more sensitive to toxins than adult and juvenile life stages as they have more permeable membranes and less developed detoxifying systems (75; 91; 92).

JUVENILE BLUE CRAB

Photo By: Corrin Flora

Endocrine disrupting chemicals (EDCs) are hormonally active chemicals that alter growth, development, reproductive, or metabolic processes adversely affecting the organism, its progeny, and/or stock viability (93; 92; 94). Endocrine disrupting chemicals include some industrial chemicals, pesticides, metals, flame retardants, plasticizers, disinfectants, prescription medications, pharmaceuticals, and personal care products. These contaminants have been found in North Carolina waters (95; 96). Endocrine disrupting chemicals can cause mortality or sub-lethal stress on shellfish and crustaceans, depending on the concentration and extent of exposure. Flame retardants (polybrominated diphenyl ethers), which have widespread occurrence in surface waters, have been linked to inhibiting molting in blue crabs (97).

Mass mortality of peeler blue crabs has been reported in the Pamlico estuary. The Department of Agriculture, Pesticide Division (DAPD) investigated a 2012 event reported to the Division of Water Resources and Marine Fisheries. The cause of the kill was found to be the pesticide bifenthrin, which is commonly used with cotton and considered highly toxic to invertebrates. Rain following the spraying of adjacent cotton fields carried runoff from the fields to the canal where the raceway intake occurred. The DAPD rules prohibit aerial application of pesticides under conditions likely to result in drift to non-target areas. However, drift of chemicals into surface waters does occur at times. The deposition of pesticides labeled toxic or harmful to aquatic life is not permitted in or near waterbodies. However, chemicals applied on land can be carried by stormwater runoff across land and ditches into surface waters. In the 2012 incident, the pesticide application did not violate label application directions, but some best management practices could have been followed to minimize impacts. After the kill, the NCMFC's Crustacean Advisory Committee requested the division look into this. The topic was discussed by the NCMFC's Habitat and Water Quality Advisory Committee, and DAPD staff spoke about the process and the specific incident. As a result of the meeting, the DAPD staff offered to increase outreach and technical assistance to farmers and additional training to pesticide applicators. Information was included on the NCDMF website and in dealer newsletters regarding what to do if a blue crab kill occurs.

Microplastics in the water column are a growing concern for aquatic organisms, including crustaceans (99). Of the numerous species documented to have ingested microplastics (pieces < 5 mm in size), bivalves and crabs are especially vulnerable (100). Microplastics enter crabs through the gills or gut, negatively impacting oxygen consumption and ion exchange. The properties of the plastics allow for adsorption of organic pollutants, toxins, and heavy metals. Analysis of microplastics in Atlantic mud crab (*Panopeus herbstii*) and eastern oyster (*Crassostrea virginica*) in Florida found crabs had two orders of magnitude more pieces of microplastics per individual, primarily fibers, than oysters (101). On average, the crabs had 4.2 pieces per individual and a mean of 20 additional pieces per individual temporarily entangled on exterior surfaces. In addition to blue crabs directly ingesting microplastics, they may accumulate them by forage on Atlantic mud crab or other species that previously ingested these plastics.

COMMERCIAL CRAB CULLING ON BOAT

Photo By: NCDMF staff

HABITAT DEGRADATION AND LOSS

As blue crabs migrate through the coastal ecosystem over their life cycle, they utilize many different habitats, including SAV, wetlands, shell bottom, and soft bottom. These habitats are described in detail in the NC Coastal Habitat Protection Plan (45) and shown in Figures 8 and 9. Portions of these habitats have been degraded or lost over time by a variety of anthropogenic sources (45), potentially impacting blue crab populations.

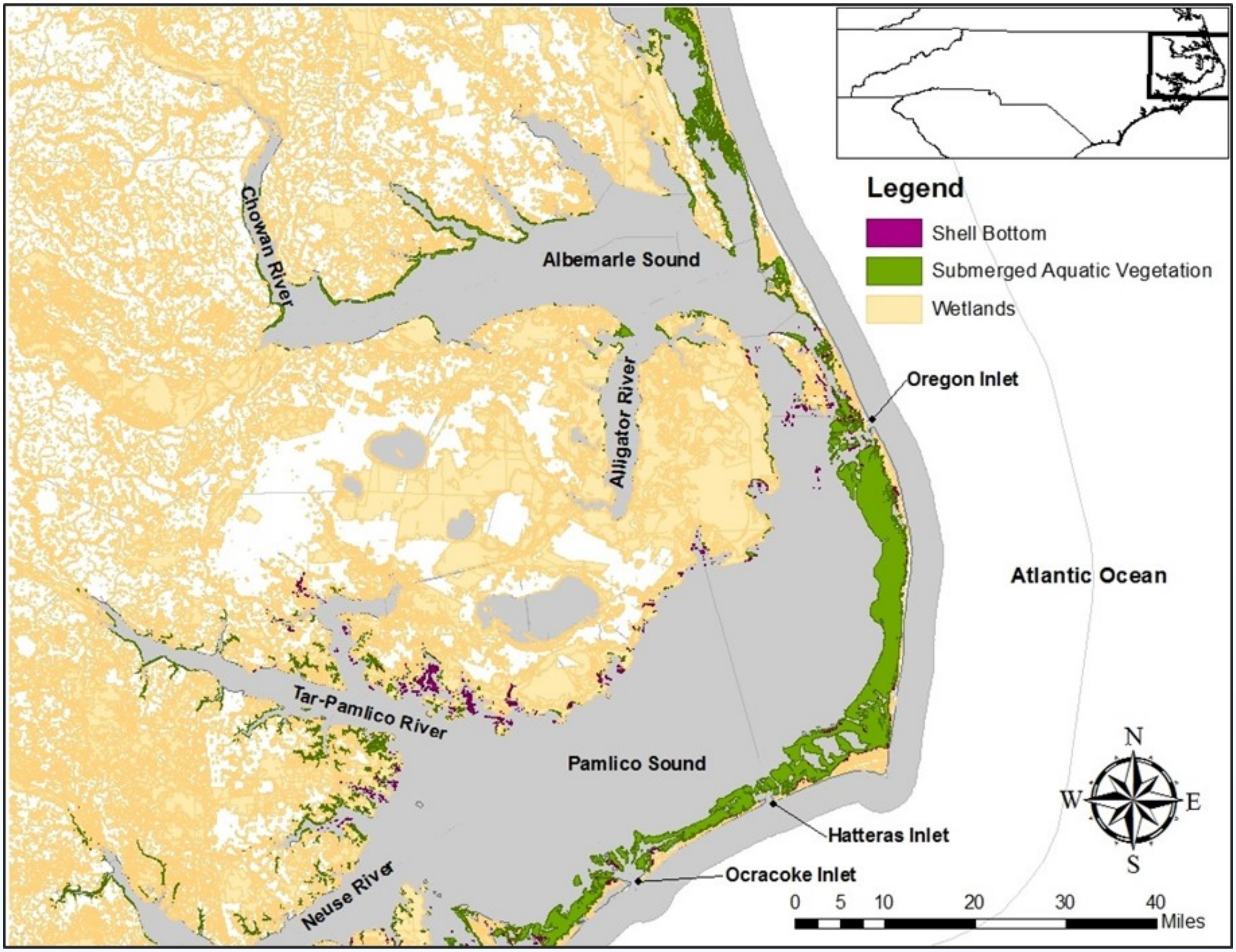


Figure 8 Location of mapped shell bottom, submerged aquatic vegetation, and wetlands – northern coast.

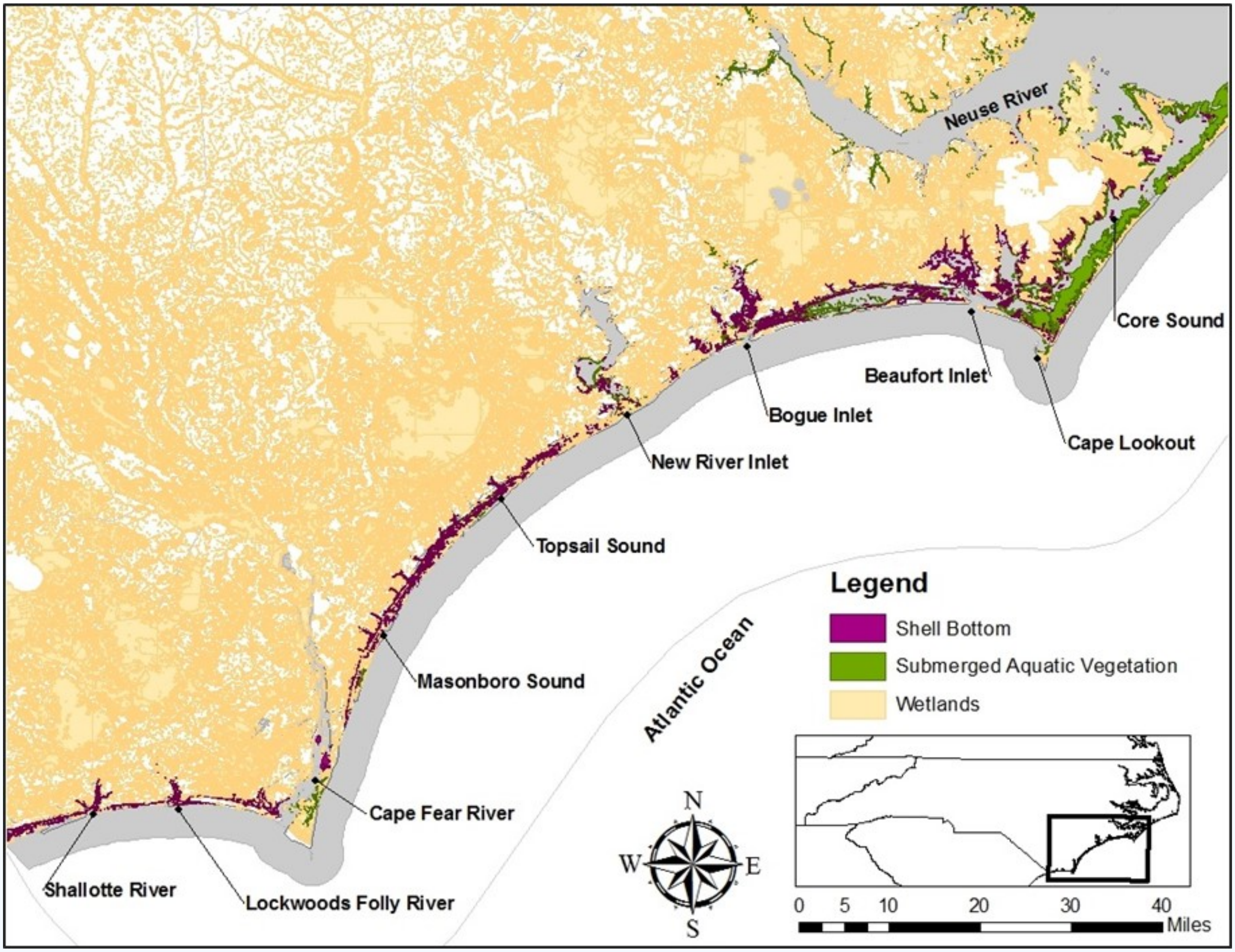


Figure 9 Location of mapped shell bottom, submerged aquatic vegetation, and wetlands – southern coast.

Submerged aquatic vegetation

The structural complexity of submerged aquatic vegetation (SAV) is a critical habitat not only for blue crabs but over 150 species of fauna, including prey for blue crabs. Post-larval and early juvenile blue crabs (< 12 mm carapace width) use SAV for initial settlement and protection while they forage and grow. Adult blue crabs also use SAV for protection while molting and overwintering. In the Albemarle-Pamlico estuarine system, most initial recruitment of juvenile blue crabs occurs in SAV beds around inlets behind the Outer Banks. However, in years with large storm events, blue crabs disperse into lower salinity habitats where they recruit into marsh habitat (5). When SAV is lacking blue crabs are forced to recruit into other habitat structure, such as marsh (5), shell bottom (102; 103), detrital matter, and woody debris (104).

Blue crabs have been shown to be more abundant in SAV than in shallow unvegetated estuarine bottoms in North Carolina and elsewhere (105; 106). Within SAV, juvenile crab density was documented to be greater where beds are large, continuous, and vegetated with dense, tall grass shoots (106; 107; 105; 108; 109; 5; 110). Using a habitat-specific demographic model to quantify the effects of habitat on population fitness, Ralph and Lipcius (111) found increased survival of age-0 blue crabs when vegetated habitats were present, which resulted in increased population growth rates.

COMMERCIAL CRAB BOAT

Photo By: Terry West

As a primary producer, SAV takes up carbon dioxide and releases oxygen into surface waters. The plants stabilize sediment and improve water clarity, which in turn enhances conditions for other habitats and organisms. Due to the important ecological functions provided by SAV to the ecosystem and multiple life stages of blue crab, reduced abundance or change in the distribution of SAV could negatively impact the blue crab population. The 2016 CHPP summarizes known distribution, temporal change, and threats (e.g. reduced water clarity from stormwater runoff, wastewater discharges, dredging, bottom disturbing gear, etc.) for navigation and fishing to SAV. In 2016, there were estimated to be at least 150,000 acres of SAV in NC. Historical change in extent has not been quantified but qualitatively known to have declined in some areas.

Wetlands

Like SAV, postlarvae and juvenile blue crabs use wetlands for foraging, refuge, and migration through the estuary (45). This includes detrital matter and woody debris from adjacent wetland vegetation, particularly in the Albemarle and Pamlico systems. Blue crabs utilize marsh edge and woody debris more than unvegetated bottom and occur more regularly in marshes with longer inundation periods (112; 113). They also use wetlands to a greater extent when SAV and oyster reefs are not present, such as in the lower salinity regions of river-dominated estuaries (12). Blue crabs in these lower salinity areas also have higher growth rates and lower predation than in the more saline waters (12). The NCDMF estuarine trawl survey data show blue crab is one of the dominant juvenile species in marshes and shallow tidal creeks (34; 114).

North Carolina’s extensive estuary is rich in wetlands, with an estimated 3,759,700 acres within the coastal region (45). However, this is approximately half of what existed pre-1800s (115). While federal and state laws have greatly reduced dredge and fill impacts to wetlands, losses still occur on a smaller scale due to development, navigational dredging, and erosion associated with wave energy and rising sea level (45).

Wetland loss lowers the habitat’s capacity to support blue crabs, trap and filter upland pollutants, and buffer storm events. Wetland losses associated with development and shoreline hardening reduce nursery habitat and food resources available for blue crab. Looking at the effect of land-use change on fish abundance, Meyer (116) found a negative correlation between abundance of juvenile blue crabs and conversion of wetlands/undeveloped forest to agriculture/development (where the development change was greater than or equal to 12%). When assessing the effect of bulkheads and living shorelines on fish and invertebrates, Scyphers et al. (117) found living shorelines supported a greater abundance and diversity of aquatic life, with blue crabs being the most clearly enhanced (300% more abundant). Predation related mortality was significantly less at vegetated shorelines than at bulkheads or riprap (118).

Shell Bottom

Oyster reefs are used as nursery habitat for early juveniles and foraging grounds for adults (12; 109). In Pamlico Sound, after initial settlement, juveniles undergo a secondary migration to shallow, less-saline waters in the upper estuaries and rivers of western Pamlico Sound (5) inhabiting oyster and wetland habitat. Blue crabs forage heavily on invertebrates and oyster spat in shell bottom (119; 120; 121). Shell bottom enhances conditions for other habitats used by blue crabs. Filter feeding shellfish improve water clarity conditions, benefiting SAV, and buffer wave energy along the shoreline reducing erosion of wetlands (122; 123; 45). For subtidal oyster reefs, the vertical height of the reef elevates oysters off the bottom, avoiding anoxic water and sedimentation and provides refuge for blue crabs during hypoxic events (121; 54; 124).

In North Carolina, shell bottom occurs on intertidal and subtidal bottom, and both are used by blue crabs (122). Based on NCDMF's Bottom Mapping Program, there are approximately 21,220 acres of shell bottom habitat in coastal waters, excluding subtidal oysters in waters greater than 15' water depth (45). It is estimated that over 90% of the subtidal oyster habitat, primarily in the Pamlico Sound system, has been lost (36). Loss was initially due to mechanical harvest of oysters in the early 1900s, followed by lack of recovery due to disease, continued harvest, and sedimentation. Current factors threatening subtidal oyster habitat are sedimentation and low DO (54; 125). The abundance of both intertidal and subtidal shell bottom habitat is limited by harvest and lack of hard substrate.

HISTORIC CRAB TRAWLING

Photo by: unknown

Inlets and Ocean Bottom

Adult female blue crabs migrate from brackish areas to high-salinity waters near ocean inlets to spawn from late spring to early fall (6). Connectivity between shell bottom, wetlands, and SAV throughout the estuary enhances the ability of blue crabs to forage and move through the system, particularly adult females migrating to their spawning grounds near inlets (126; 112).

OREGON INLET NORTH CAROLINA

Photo by: Terry West

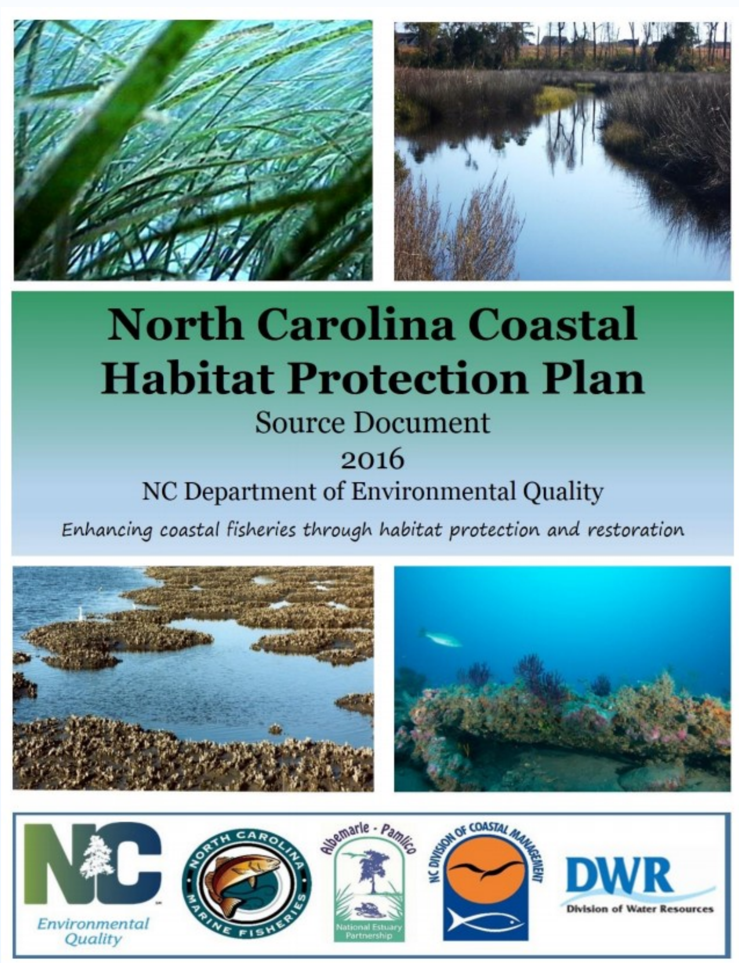
Females rely on high-salinity cues to ensure eggs are released for development on the continental shelf. Ogburn and Habegger (127) used Southeast Area Monitoring and Assessment Program (SEAMAP) data from 1990 to 2011 to assess spawning habitat in the South Atlantic Bight. Using the reproductive condition of mature females as an indicator of spawning, they found blue crabs spawned throughout the South Atlantic Bight and as far as 13 km offshore. In North Carolina, mature females were most abundant in the ocean in the summer, where approximately 84% had spawned and had only remnant eggs. Results of Ramach et al. (128) suggest inlets serve as migration corridors to the ocean where eggs are released and dispersed. The fishing effort on sponge crabs while migrating to and through inlet corridors for spawning could negatively impact the blue crab population.

HABITAT AND WATER QUALITY PROTECTION

Coastal Habitat Protection Plan

As noted earlier in the Introduction, the FRA statutes mandate the Department to prepare and periodically update the CHPP (G.S. 143B 279.8). The legislative goal for the CHPP is long-term enhancement of the coastal fisheries associated with coastal habitats. The plan provides a framework for management actions to protect and restore habitats critical to North Carolina’s coastal fishery resources. Three commissions have regulatory jurisdiction over the coastal resources, water, and marine fishery resources including the Marine Fisheries Commission (NCMFC), Coastal Resources Commission (CRC), and Environmental Management Commission (EMC). Habitat recommendations related to fishery management can be addressed directly by the NCMFC. Other habitat recommendations not under NCMFC authority (e.g. water quality management) can be addressed through the CHPP implementation process. The CHPP helps ensure consistent actions among these three commissions as well as their supporting DEQ agencies.

The CHPP describes and documents the use of habitats by species supporting coastal fisheries, the status of these habitats, and the impacts of human activities and natural events on those habitats. Fish habitat is defined as freshwater, estuarine, and marine areas that support juvenile and adult populations of economically important fish, shellfish, and crustacean species (commercial and recreational), as well as forage species important in the food chain (45).



The CHPP recommends that some areas of fish habitat be designated as “Strategic Habitat Areas” (SHAs). SHAs are defined as specific locations of individual fish habitat or systems of habitat that have been identified to provide critical habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity. Additionally, the CHPP focuses on the fish habitat and threats to the habitat. The process of identifying and designating SHAs was completed in 2018 with the approval of nominated SHAs by the NCMFC and field verification is underway. The NCMFC also has several rules in place that protect blue crab habitat. Some rules prohibit bottom disturbing gear in specific areas, others designate sensitive fish habitat such as nursery areas and SAV beds, and with applicable gear restrictions (see Appendix 4.6). Descriptive boundaries are included under the 15A NCAC 03R rules. Figures 10 and 11 provide a visual representation of several rule categories of these habitat gear related rules.

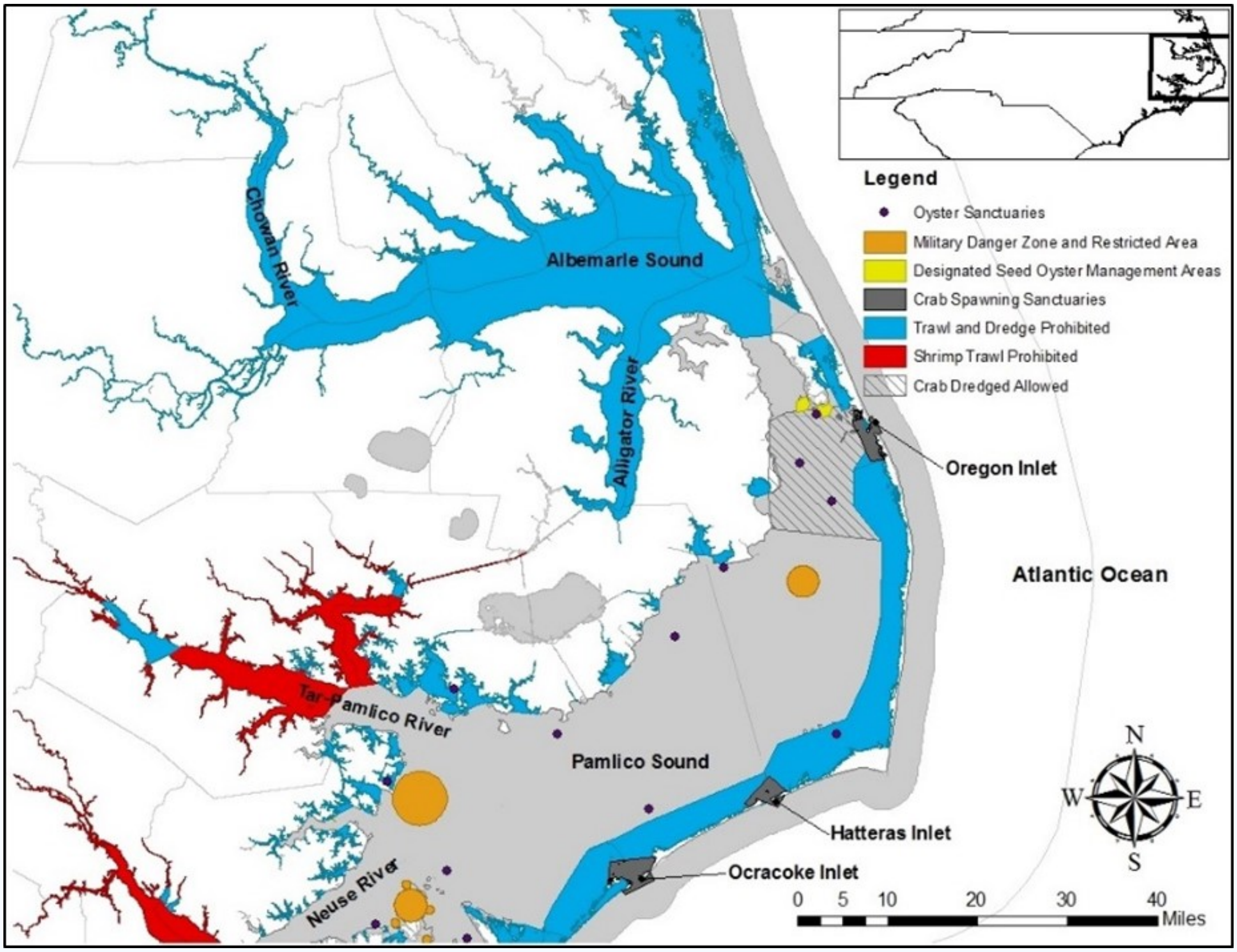


Figure 10 Estuarine areas where bottom disturbing gear is prohibited year-round or seasonally – northern coast.

BLUE CRAB CLAW
Photo By: Jeff Dobbs

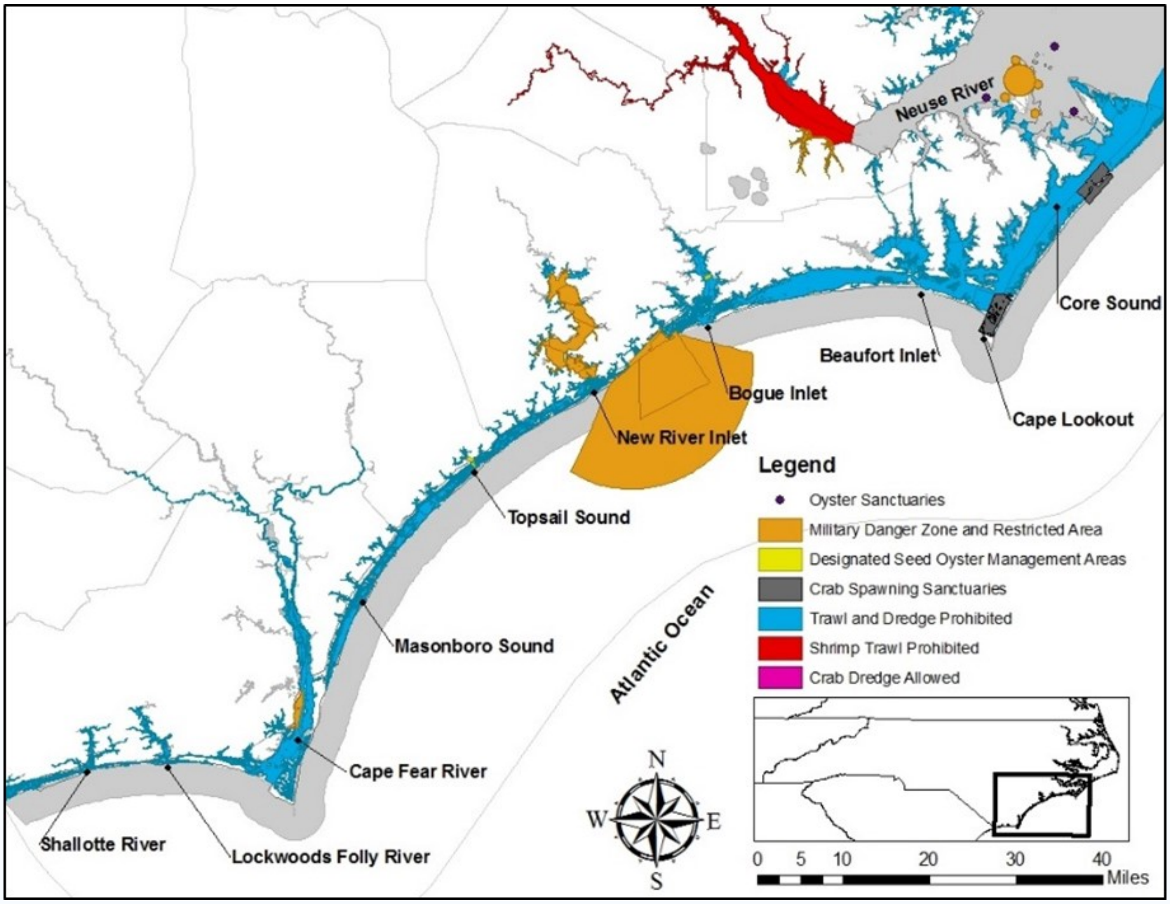


Figure 11 Estuarine areas where bottom disturbing gear is prohibited year-round or seasonally – southern coast.

Authority of Other Agencies

The North Carolina Department of Environmental Quality (NCDEQ) has several divisions responsible for rulemaking, permitting, certification, technical and financial assistance, planning, and monitoring activities that impact the coastal water quality or habitat. The North Carolina Division of Coastal Management (NCDCM) is responsible for development permits along the estuarine shoreline in 20 coastal counties. Wetland development activity throughout North Carolina is primarily permitted through the US Army Corps of Engineers (USACE) and Division of Water Resources (DWR 401 certification program). The DWR has established a water quality classification and standards program for “best usage” to promote the protection of unique and special pristine waters with outstanding resource values. Water quality standards and required management strategies for point and nonpoint sources differ by water quality classification such as High Quality Waters, Outstanding Resource Waters, Nutrient Sensitive Waters, and Water Supply. Various federal and state environmental and resource agencies evaluate projects proposed for permitting and provide comments and recommendations to the DCM, DWQ, and USACE on potential habitat and resource impacts. The South Atlantic Fishery Management Council (SAFMC) has designated Essential Fish Habitat – Habitat Areas of Particular Concern (EFH-HAPC) for federally managed species, which can provide additional protection from development projects. Several habitat areas used by blue crab are designated as EFH-HAPC, including SAV and inlets. Habitat protection relies on enforcement, the efforts of commenting agencies to evaluate impacts, and the incorporation of recommendations into permitting decisions. Habitats are also protected through the acquisition and management of natural areas as parks, refuges, reserves, or protected lands by public agencies and/or private groups.

SIGNIFICANT WEATHER EVENTS

Significant weather events such as droughts and hurricanes can alter physio-chemical parameters and consequently influence the occurrence and distribution of fish and habitat in coastal North Carolina waters. Predominant winds, currents, and rainfall at a certain time of year highly affect annual recruitment success of larvae into nursery habitat. Although indirect, blue crabs are affected by natural disturbances of their environment. In particular, hurricanes can affect blue crab harvest in the short-term by concentrating blue crabs in areas where they are vulnerable to fishing gear (129). Significantly lower statewide blue crab landings in 2000 compared to landings in the late 1990s were attributed to prolonged water quality degradation in the Pamlico estuarine system following the 1999 hurricanes (130). In 1989, 2000, and 2003, lower catch per unity effort of blue crabs from NCDMF's estuarine trawl survey coincides with hurricanes and the three highest years of rainfall from 1980 to 2016 (Figure 12).

If storms are too extreme, above normal freshwater input can lower salinity to the point that megalopae and juvenile blue crab mortality occur, negating the benefits of increased settlement. However, not all the effects of hurricanes are detrimental. For example, peaks in post-larval blue crab settlement coincided with hurricane tracks coming from a southwesterly direction (4). A large ingress of post-larval blue crabs could make a significant contribution to the blue crab population.

Hurricanes can cause flooding, flush pollutants from the upper estuarine bottom, cause sedimentation over oyster reefs, and erode wetland shorelines. While these extreme weather events have always occurred, there is evidence that the frequency and severity of minor (non-storm event) nuisance flooding and hurricanes on the east and Gulf coasts are increasing (131; 132; 133).

Major droughts occurred in North Carolina during 2000-2002 and 2007-2008 (45). The drought of 2007-2008 was the worst in North Carolina since recordkeeping began on the subject in 1895. The cycle of flood and drought years has a significant impact on the water quality and SAV by reducing freshwater input and could be a factor in blue crab recruitment success (Figure 12).

STORM OVER NORTH CAROLINA

Photo By: Corrin Flora

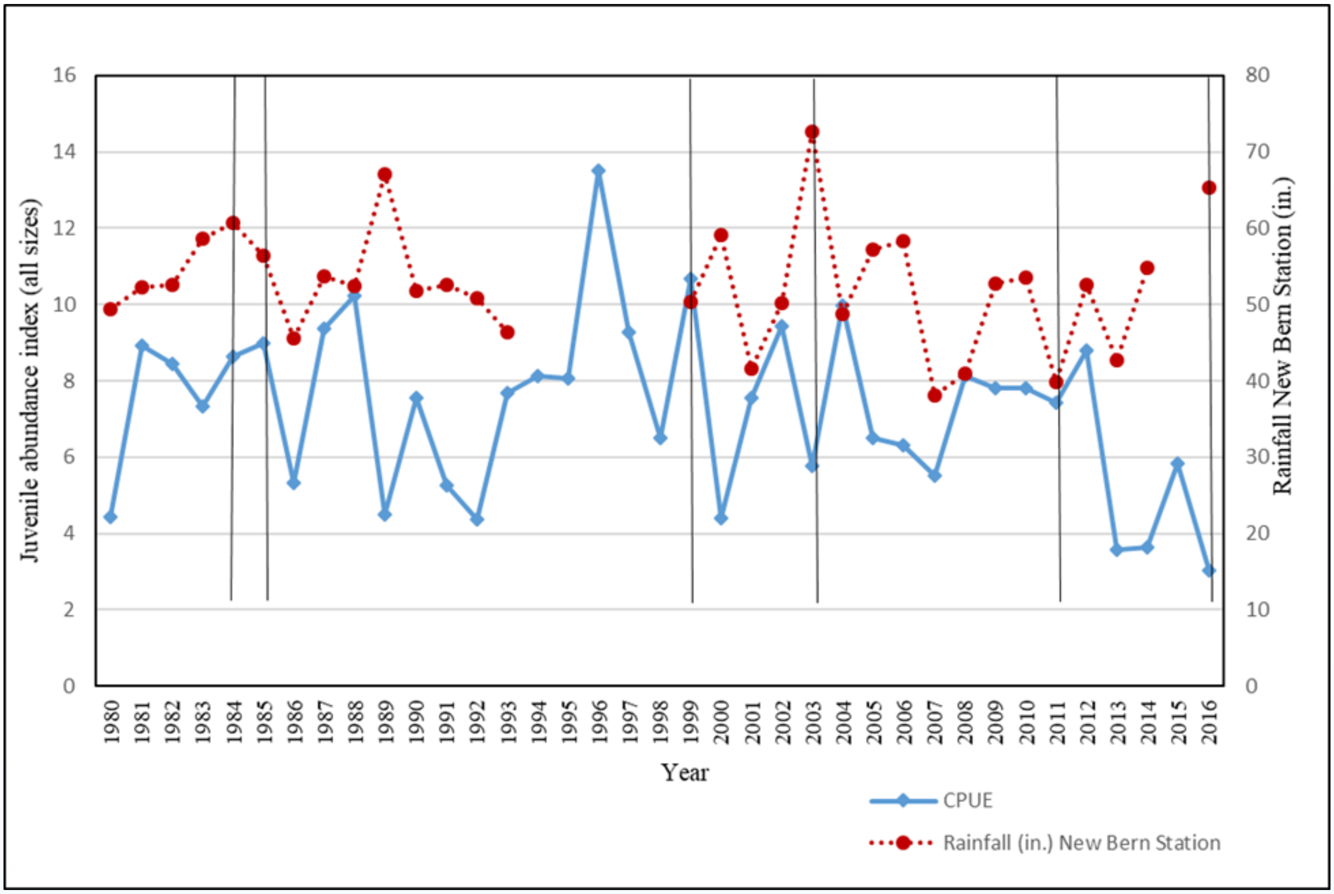


Figure 12 Annual rainfall from the New Bern station and juvenile abundance index (CPUE, all crab sizes) in New Bern, NC, 1980-2016. Source – National Weather Service and NCDMF data. Black vertical lines are years with major hurricane landfall events in NC.

A warming trend in air temperature is the primary driver of climate change that can alter the distribution and health of fish and their habitat. The 2014 National Climate Assessment summarizes observed and expected climate change and impacts regionally and overall in the U.S. (132). Potential changing oceanographic conditions of warming temperatures and rising sea level have large implications to North Carolina's estuarine system including: accelerated wetland loss, degraded water quality, loss of SAV, degradation of oyster reefs, and a more open estuary due to barrier island breaching (45). Crustaceans and mollusks are at risk due to increasing acidification of waters associated with increasing carbon dioxide levels. In Puget Sound, Washington, oyster hatcheries have observed high mortality of larvae and spat due to the inability to form their calcareous shells (134). Crustaceans with good osmoregulation tend to be less vulnerable and calcification of carapaces may not change but could be more energetically costly.

DISEASE AND PARASITES

Diseases and parasites observed in blue crabs from North Carolina include bacterial infections (shell disease), a dinoflagellate parasite *Hematodinium sp*., an amoeba parasite *Paramoeba perniciosa* (gray crab disease), and a microsporidian parasite *Ameson michaelis* (cotton crab disease). Infection rates of the parasitic dinoflagellate *Hematodinium perezi* in blue crabs along the Atlantic and Gulf coasts can exceed 50% and is usually lethal (135). A Gulf coast study found shell disease present in blue crabs at a rate of 55%, and *Vibrio spp.* present in the hemolymph of 22% of blue crabs (136). The prevalence of these in North Carolina is unknown. In 1987, an extreme outbreak of shell disease was observed in the Pamlico River (137). The chronic presence of shell disease was suggested as a possible factor contributing to a significant, progressive decline in blue crab landings in the Pamlico River from 1985 to 1989 (138). Weinstein et al. (139) found elevated levels of arsenic, aluminum, manganese, and other metals from blue crabs in contaminated waters of the Pamlico River, compared to those in a relatively uncontaminated area of the Albemarle Sound. Gray crab disease has not been a major problem, though there have been periodic outbreaks causing localized mortalities (140). Cotton crab disease was identified as the suspected cause of excessive mortality and weakened peelers and soft crabs in northern Outer Banks, NC shedding operations during 1999. Prevalence and lethality of diseases and parasites in blue crabs can increase under stressful conditions such as poor water quality (141). A listing of potential parasites, diseases, symbionts, and other associated organisms reported from blue crabs is presented in Guillory et al. (61).

INVASIVE SPECIES

Invasive species are plants, animals, and other organisms not native to an ecosystem that may cause economic or environmental harm by affecting the health of organisms, displacing native species, or altering natural habitat conditions. Non-native species introductions are a growing and imminent threat to living aquatic resources throughout the United States. Pathways of entry to North Carolina waters include release from aquaria and mariculture facilities, boat movement, discharge of ballast water, attachment to fishing gear, and through association with other non-native species (142; 143). Often fish species are introduced deliberately for sport-fishing purposes.

Blue catfish (*Ictalurus furcatus*) was introduced as a sport fish into Virginia waterways and has entered into the waters of North Carolina. Blue catfish have been found to regularly consume blue crabs in the Chesapeake Bay, VA during fall and winter months with blue crab estimated at 30% of blue catfish diet during this time (144). Another non-native species known to consume blue crabs is the Asian tiger shrimp (*Penaeus monodon*). Tiger shrimp were first reported to the NCDMF in 2008. The population is believed to be small in North Carolina waters. However, in a mesocosm experiment, blue crabs less than 25mm carapace width were often located, attacked, and successfully consumed by Asian tiger shrimp (145). Preying on blue crabs, Asian tiger shrimp and blue catfish have the potential to negatively impact the blue crab population.

The invasive Rhizocephalan parasitic barnacle (*Loxothylacus panopaei*) has been reported in Xanthid crabs (*Eurypanopeus depressus*) in the Masonboro and Rachel Carson National Estuarine Research Reserves (146). The parasite impacts the host by impeding reproduction, halting growth, and reducing feeding. These barnacles, which originated from the Gulf of Mexico, are known to also infect blue crabs (147), although their presence in blue crabs in North Carolina has not been investigated. Infected blue crabs in Texas were found to rarely burrow below the sediment (148), which would increase vulnerability to predation and environmental conditions.

Juvenile blue crabs use submerged aquatic vegetation beds as a source of refuge. Non-native aquatic plants can cause severe environmental impacts, outcompeting and displacing native plants. Large expanses of coastal rivers and streams in North Carolina were previously blocked by mats of alligatorweed (*Alternanthera philoxeroides*) and Eurasian watermilfoil (*Myriophyllum spicatum*; 149). These plants were successfully cleared through chemical treatment, and waterways remain open with limited maintenance control. However, studies in the Chesapeake Bay found as non-native plant density increased, so did native plant density (150) that function as nursery areas for juvenile blue crabs (151). Similarly, NCDMF sampling data have found juvenile blue crabs and other species in Eurasian watermilfoil in low salinity waters such as Kitty Hawk Bay and Currituck Sound. When non-native spread is assessed on a local scale, habitats may be altered to promote native plant spread by reduced water velocity, increased sedimentation, sediment stabilization, and increased water clarity. Control, research, and education are the three key elements of a successful aquatic weed control program. For more information on invasive species see the North Carolina Coastal Habitat Protection Plan 2016 (45) and the North Carolina Aquatic Nuisance Species Management Plan (152).

BYCATCH IN OTHER FISHERIES

Due to the broad environmental and habitat tolerances of blue crabs, they are found in the same areas as many of North Carolina's commercially important finfish and shellfish species. This habitat sharing, in part, causes blue crabs to be caught incidentally as bycatch in fisheries targeting other species.

Crab pots are the primary gear used to harvest blue crabs. These, along with other gears that target blue crab, make up over 99% of blue crab harvest; however, they are caught as bycatch with other types of gear (38). Blue crabs harvested as bycatch make up less than 0.5% of the total landings, ranging from 32,567 (2016) to 79,993 pounds (2014) in the past ten years (Figure 13).

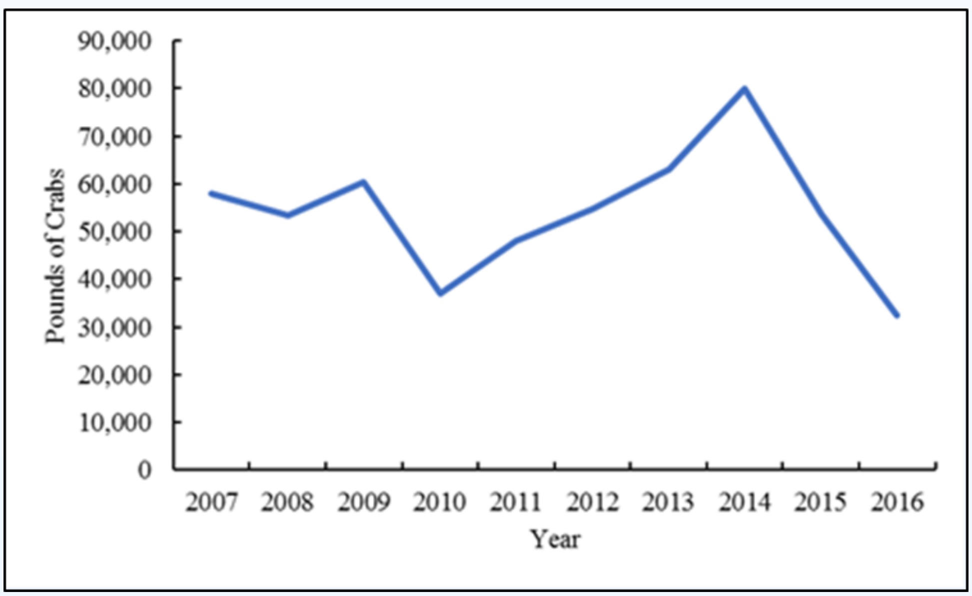


Figure 13 Pounds of blue crabs harvested as bycatch from all fisheries, 2007-2016.

Studies have found blue crabs make up between 6% and 30% of total catch by number in the estuarine gill net fishery, typically accounting for the majority of non-finfish catch (153; 154; 155; 156; 157; 158). Hassel (157) found blue crab bycatch increased as gill net mesh size decreased. Shrimp trawls are also a significant source of blue crab bycatch. Blue crabs make up 0.14% of catch by weight in otter trawls (159), and 2.03% by weight in skimmer trawls (160).

Blue crabs are also discarded as bycatch in many fisheries. They can be discarded for a variety of reasons such as limited quantity, sublegal size, or difficulty removing from gear causing crabs to be unmarketable after removal (e.g. gill nets). Gill nets are the only gear with reliable discard estimates of blue crab from commercial catches in North Carolina. This discard data is collected as part of the estuarine gill net observer program in which observers sample the catch of fishermen when they fish their gear. Over the past five years, 80% of the nearly 24 thousand observed crabs caught in gill nets were discarded (Table 24). There is high mortality associated with removal from this gear because when crabs become entangled in the webbing, it is very difficult and time-consuming to remove them without harming the crab. Due to current data limitations, it is not feasible to estimate the total discard mortality of blue crabs in all fisheries in North Carolina. However, from the estimates available, these discards may represent a significant source of fishing mortality.

BLUE CRAB SHEDDING EXOSKELETON

Photo By: Brandi Salmon

Table 24 Number of observed blue crabs kept and discarded from the estuarine gill net observer program, 2013-2017.

Year	Kept Crabs	Discarded Crabs	Total	Discard Percentage	Observed Trips with Number of Crabs Recorded	Total Observed Trips (Onboard)	Total Estuarine Gill Net Trips
2013	741	4,751	5,492	87%	451	661	29,128
2014	1,883	5,613	7,496	75%	540	827	21,048
2015	1,076	2,997	4,073	74%	413	784	17,385
2016	681	2,706	3,387	80%	353	656	16,859
2017	284	2,940	3,224	91%	315	740	20,459
Total	4,665	19,007	23,672	80%	2,072	3,668	104,879

MANAGEMENT STRATEGIES UNDER BLUE CRAB AMENDMENT 3

Achieving sustainable harvest

- A closed season in which the region will remain closed for the entirety [replaced the variable pot closure period(s) prior to Amendment 3]
    - Jan. 1 - 31 north of the Highway 58 bridge to Emerald Isle
    - March 1 - 15 south of the Highway 58 bridge
- A 5-inch minimum size limit for mature female crabs statewide
- Retain the prohibition on harvest of immature female hard crabs statewide, established in the 2016 Revision
- Retain the current 5% cull tolerance, established in the 2016 Revision
- Adopt an adaptive management framework based on the stock assessment:
    - Update the stock assessment at least once between full reviews of the FMP, timing at the discretion of the division
    - If the stock is overfished and/or overfishing is occurring or the blue crab stock is not projected to meet the sustainability requirement, management measures shall be adjusted using the director's proclamation authority
    - If the stock is not overfished and/or overfishing is not occurring management measures may be relaxed provided it will not jeopardize the sustainability of the blue crab stock
    - Any quantifiable management measure, including those not explored in this paper, with the ability to achieve sustainable harvest (as defined in the stock assessment), either on its own or in combination, may be considered

Non-quantifiable management measures

- Maintain number of cull rings in pots to 3, established in the 2016 Revision
- Maintain one cull ring placed within one full mesh of the corner and the apron in the upper chamber of the pot, established in 2016 Revision
- Remove cull ring exemptions for Newport River and eastern Pamlico Sound and prohibit designation of exempt areas in future
- Maintain prohibited harvest of dark sponge crabs from April 1 through April 30, established in 2016 Revision

Water quality

- Work with other commissions and state agencies to address water quality issues affecting blue crab. Strategies selected are:
    - Highlight problem areas and advise other regulatory agencies
    - Create a joint interagency work group
    - Support the Clean Water Act
    - Task the CHPP steering committee to prioritize blue crab water quality impacts [NCMFC identified as the highest priority, Option 4]
    - Send letters to other state agencies sharing concerns about water quality and Best Management Practices
    - Invite other agencies to future NCMFC meetings to present their efforts to address water quality
    - Initiate public outreach on how to report crab and fish kills

Water quality (continued)

- Division habitat staff shall regularly report back to the Habitat and Water Quality and Shellfish/Crustacean ACs with progress on each selected management water quality issue

Crab spawning sanctuaries

- Maintain existing boundaries for the Oregon, Hatteras, and Ocracoke inlets crab spawning sanctuaries; expand the existing crab spawning sanctuary in Barden Inlet and move the boundary of the Drum Inlet sanctuary to encompass Ophelia Inlet
- Maintain existing mechanical gear restrictions and prohibition of crab harvest from March 1 -August 31
- Establish new crab spawning sanctuaries in Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Cape Fear River, Shallotte, Lockwoods Folly and Tubbs inlets
- NCDMF recommended boundary approved for Cape Fear River Inlet sanctuary
- Closure period of March 1 through October 31 for new sanctuaries with the same gear and harvest restrictions as existing sanctuaries

Terrapin excluder devices

Adopted the framework and criteria for identifying diamondback terrapin management areas, adding a step to bring proposed management areas back to the NCMFC following committee meetings at the next regularly scheduled meeting for approval. The framework is this document in total and consists of the following criteria:

- ♦ Step 1 Determine NCDMF approved terrapin excluder device types and sizes to be required
- ♦ Step 2 Determine dates when terrapin excluder devices will be required
- ♦ Step 3 Identify the zone of potential diamondback terrapin interaction with crab pots
- ♦ Step 4 Validate diamondback terrapin presence and overlap with zone of potential crab pot interaction
- ♦ Step 5 Determine appropriate Diamondback Terrapin Management Area (DTMA) boundaries
- ♦ Step 6 Develop initial issue paper detailing the proposed DTMA, presented issue to the appropriate regional committee, and receive public comment
- ♦ Step 7 NCMFC review documents and take action to adopt, adopt with modification, or deny proposed DTMA
- ♦ Step 8 Implement adopted DTMA by proclamation and incorporate the finalized issue paper as a revision to the FMP

Bottom disturbing gear

- Retain prohibiting taking of crabs with crab dredges, established in the 2016 Revision
- Reduce the bycatch limit of crabs from oyster dredges to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less
- Prohibit the taking of crab by trawls in areas where the taking of shrimp with trawls are already prohibited in the Pamlico, Pungo, and Neuse rivers

RESEARCH RECOMMENDATIONS

Biological/Stock Assessment/Fishery

- Implement long-term monitoring of blue crab discards in other fisheries (e.g., gill net, trawl). [High]
- Develop statewide fishery-independent survey(s) to monitor the abundance of all blue crab life stages. [High]
- Expand time and area coverage of existing fishery-independent surveys. [High]
- Better characterize the magnitude of recreational harvest. [High]
- Develop better estimates of life-history parameters, especially growth and natural mortality. [High]
- Explore alternative biological reference points. [High]
- Research interaction rates of non-target species in the blue crab fishery and identify factors that may lead to interactions (e.g., migration patterns, habitat utilization). [High]
- Characterize the harvest and discard of blue crabs from crab shedding operations. [Medium]
- Explore alternative model types. [Medium]
- Investigate and support research on promising methods to age blue crabs. [Low]
- Evaluate the genetic stock structure of blue crabs within North Carolina and the magnitude of mixing between populations. [Low]
- Identify programs outside the NCDMF that collect data of potential use to the stock assessment of North Carolina's blue crabs. [Low]

NCDMF JUVENILE TRAWL SURVEY

Photo By: Corrin Flora

Ecosystem

- Identify biological characteristics of submerged aquatic vegetation beds of ecological value to blue crab and implement restoration and conservation measures. [High]
- Research mature female migration routes and seasonal habitat use (e.g., inlets, staging areas). [High]
- Research gear modifications to minimize interactions with non-target species (e.g., diamondback terrapin) in the blue crab fishery. [High]
- Research the impacts of land use activities and shoreline clearing on water quality and the blue crab stock. [High]
- Research the impact of endocrine disrupting chemicals on the various life stages of blue crabs and ways to reduce their introduction into estuarine waters, including discharge from wastewater treatment plants. [High]
- Research the impact of increased predator abundance on the blue crab stock. [Medium]
- Identify key environmental factors that significantly impact North Carolina's blue crab stock and investigate assessment methods that can account for these environmental factors. [Medium]
- Identify, map, and protect habitat of ecological value to blue crab (in particular juvenile habitat) and implement restoration and conservation measures. [Medium]
- Assess the impact of inlet dredging activities on mature female blue crabs. [Medium]
- Implement monitoring of hazardous events (e.g., hurricane, extreme hot or cold weather) affecting blue crab population dynamics and harvest. [Medium]
- Research the extent, causes, and impacts of hypoxia and anoxia on blue crab behavior and population abundance in estuarine waters. [Medium]
- Research the impact of invasive species (e.g., blue catfish) on the blue crab stock. [Medium]

Socio/Economic

- Research and identify key market forces and their effects on the blue crab industry. [Low]

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APPENDICES

APPENDIX 1. GLOSSARY OF BIOLOGICAL TERMS

Abundance Index
A relative measure of the weight or number of fish in a stock, a segment of the stock (e.g. the spawners), or an area. Often available in time series, the information is collected through scientific surveys or inferred from fishery data.

Age
The number of years of life completed, here indicated by an Arabic numeral, followed by a plus sign if there is any possibility of ambiguity (age 1, age 1+).

Assessment
A judgment made by a scientist or scientific body on the state of a resource, such as a fish stock (e.g. size of the stock, potential yield, on whether it is over- or underexploited), usually for the purpose of passing advice to a management authority.

Barrier Island
A sedimentary island, generally elongate and low, that is built by longshore transport or wave action parallel to the coast.

Benthic
1. Defining a habitat or organism found on the sea bottom10;
2. Of or pertaining to the seafloor (or bottom) of a water body.

Bloom
A sudden increase in the abundance of alga or phytoplankton resulting in a contiguous mass of highly concentrated phytoplankton in the water column.

Buffer Zone
The area that separates the core from areas in which human activities that threaten it occur.

Bycatch
Fish other than the primary target species that are caught incidental to the harvest of the primary species. Bycatch may be retained or discarded. Discards may occur for regulatory or economic reasons.

Bycatch Reduction Device (Excluder)
A device inserted in a fishing gear (usually trawl nets, close to the codend) to allow escapement, alive, of unwanted (non-target and prohibited) species (e.g. jellyfish), smaller fish (juveniles), and threatened or endangered species (e.g. sea turtles, marine mammals).

Catchability
In general, the extent to which a stock is susceptible to fishing.

Carapace
The hard, upper shell of a turtle, crustacean, or arachnid.

Catch Per Unit (of) Effort (CPUE)
The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; e.g. number of fish taken per 1,000 hooks per day or weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance. Also called: catch per effort, fishing success, availability.

Cohort
1. In a stock, a group of fish generated during the same spawning season and born during the same time period;
2. In cold and temperate areas, where fish are long-lived, a cohort corresponds usually to fish born during the same year (a year class). For instance, the 1987 cohort would refer to fish that are age 0 in 1987, age 1 in 1988, and so on. In the tropics, where fish tend to be short lived, cohorts may refer to shorter time intervals (e.g. spring cohort, autumn cohort, monthly cohorts).

Commercial Fishery
A term related to the whole process of catching and marketing fish and shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses.

Crustaceans
A group of freshwater and saltwater invertebrates with jointed legs and a hard shell of chitin. Includes shrimps, crabs, lobsters, and crayfish.

Current
A horizontal movement of water.

Decline
A decline is a reduction in the number of individuals, or a decrease of the area of distribution, the causes of which are either not known or not adequately controlled. It need not necessarily still be continuing. Natural fluctuations will not normally count as part of a decline, but an observed decline should not be considered part of a natural fluctuation unless there is evidence for this. A decline that is the result of harvesting that reduces the population to a planned level, not detrimental to the survival of the species, is not covered by the term.

Density-Dependence
The dependence of a factor influencing population dynamics (such as survival rate or reproductive success) on population density. The effect is usually in the direction that contributes to the regulative capacity of a stock.

Detritus
Dead organic matter and the decomposers that live on it; when broken up by decomposers, detritus provides energy to many coastal ecosystems.

Discard
To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Ecosystem
A geographically specified system of organisms, the environment, and the processes that control its dynamics. Humans are an integral part of an ecosystem.

Effort
The amount of time and fishing power used to harvest fish; includes gear size, boat size, and horsepower.

Epifauna
Benthic fauna living on the substrate but not burrowing into it (as on a hard seafloor) or living on other organisms.

Escapement
The number or proportion of fish surviving (escaping from) a given fishery at the end of the fishing season and reaching the spawning grounds. The term is generally used for salmon management.

Essential Fish Habitat (EFH)
Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. 1802(10)). The EFH guidelines under 50 CFR 600.10 further interpret the EFH definition as follows: Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

Estimated Discard Mortality
Estimates of discards can be made in a variety of ways, including samples from observers and logbook records.

Estuarine
1. Relating to or formed in an estuary (e.g. estuarine currents; estuarine animals);
2. Belonging to an estuary (river mouth), an area in which sea water is appreciably diluted by fresh water from rivers.

Estuary
A coastal ecological ecosystem that is partially enclosed, receives freshwater input from land, and has a horizontal fresh-salt salinity gradient; the average salinity of estuarine waters is defined as being 30 practical salinity units (PSU) for at least 1 month per year.

Exclusive Economic Zone (EEZ)
The EEZ is the area that extends from the seaward boundaries of the coastal states (3 nautical miles (n.mi.) in most cases, the exceptions are Texas, Puerto Rico and the Gulf coast of Florida at 9 n.mi.) to 200 n.mi. off the U.S. coast. Within this area the United States claims and exercises sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources.

Exoskeleton
A rigid external covering for the body in some invertebrate animals, especially arthropods, providing both support and protection.

Ex-Vessel
Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain (at the point of landing) for the catch is an ex-vessel price.

Fecundity
The potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity usually increases with age and size. The information is used to compute spawning potential.

Finfish
Vertebrate and cartilaginous fishery species, not including crustaceans, cephalopods, or other mollusks.

Fish
Used as a collective term, includes mollusks, crustaceans and any aquatic animal which is harvested.

Fish Stock
The living resources in the community or population from which catches are taken in a fishery. Use of the term fish stock usually implies that the particular population is more or less isolated from other stocks of the same species and hence self-sustaining. In a particular fishery, the fish stock may be one or several species of fish but here is also intended to include commercial invertebrates and plants.

Fisheries Management
The integrated process of information gathering, analysis, planning, decision making, allocation of resources, and formulation and enforcement of fishery regulations by which the fisheries management authority controls the present and future behaviors of the interested parties in the fishery in order to ensure the continued productivity of the living resources.

Fishery
1. Generally, a fishery is an activity leading to harvesting of fish. It may involve capture of wild fish or raising of fish through aquaculture;

2. A unit determined by an authority or other entity that is engaged in raising or harvesting fish. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, and purpose of the activities;
3. The combination of fish and fishers in a region, the latter fishing for similar or the same species with similar or the same gear types.

Fishery-Dependent
Data collected directly on a fish or fishery from commercial or sport fishermen and seafood dealers. Common methods include logbooks, trip tickets, port sampling, fishery observers, and phone surveys.

Fishery-Independent
Characteristic of information (e.g. stock abundance index) or an activity (e.g. research vessel survey) obtained or undertaken independently of the activity of the fishing sector. Intended to avoid the biases inherent to fishery-related data.

Fishery Management Plan (FMP)
1. A document prepared under supervision of the appropriate fishery management council for management of stocks of fish judged to be in need of management. The plan must generally be formally approved. An FMP includes data, analyses, and management measures;
2. A plan containing conservation and management measures for fishery resources, and other provisions required by the Magnuson-Stevens Act, developed by fishery management councils or the Secretary of Commerce.

Fishery Management Unit
A fishery or a portion of a fishery identified in a fishery management plan (FMP) relevant to the FMP's management objectives. The choice of stocks or species in an FMU depends upon the focus of FMP objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives.

Fishery Models
Simplified representations of the fisheries complex reality. May or may not be a mathematical representation.

Fishing
Any activity, other than scientific research conducted by a scientific research vessel, that involves the catching, taking, or harvesting of fish; or any attempt to do so; or any activity that can reasonably be expected to result in the catching, taking, or harvesting of fish and any operations at sea in support of it.

Fishing Effort
The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time (e.g. hours trawled per day, number of hooks set per day, or number of hauls of a beach seine per day). When two or more kinds of gear are used, the respective efforts must be adjusted to some standard type before being added. Sometimes referred to as effective fishing effort.

Fishing Gear
The equipment used for fishing (e.g. gill net, hand line, harpoon, haul seine, long line, bottom and midwater trawls, purse seine, rod-and-reel, pots and traps). Each of these gears can have multiple configurations.

Fishing Mortality (F)
1. F stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year;
2. A measurement of the rate of removal from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in one year. Instantaneous mortality is that percentage of fish dying at any one time.

Food Chain
The transfer of energy from the source in plants through a series of organisms with repeated eating and being eaten. At each transfer, a large proportion of the potential energy is lost as heat. The shorter the food chain (or the nearest the organism is from the beginning of the food chain), the greater the available energy which can be converted in biomass.

Forage Species
Species used as prey by a larger predator for its food. Includes small schooling fishes such as anchovies, sardines, herrings, capelin, smelts, and menhaden, and invertebrates such as squid.

Gear
A fishing gear is a tool used to catch fish, such as hook-and-line, trawl net, gill net, pot, trap, spear, etc.

Gear Restriction
1. A type of input control used as a management tool whereby the amount and/or type of fishing gear used by fishers in a particular fishery is restricted by law;
2. Limits placed on the type, amount, number, or techniques allowed for a given type of fishing gear.

Growth
Usually an individual fish’s increase in length or weight with time. Also may refer to the increase in numbers of fish in a population with time.

Habitat
1. The environment in which the fish live, including everything that surrounds and affects its life, e.g. water quality, bottom, vegetation, associated species (including food supplies);
2. The locality, site and particular type of local environment occupied by an organism.

Harvest
The total number or weight of fish caught and kept from an area over a period of time. Note that landings, catch, and harvest are different.

Health
The condition of the marine environment from the perspective of adverse effects caused by anthropogenic (human) activities, in particular habitat destruction, changed sedimentation rates and the mobilization of contaminants. Such condition refers to the contemporary state of the ocean, prevailing trends, and the prognosis for improvement or deterioration of its quality.

Incidental Take
The "take" of protected species (such as listed salmon, marine mammals, sea turtles, or sea birds) during fishing. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct.

Indicators
1. A variable, pointer, or index. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and action;
2. Signals of processes, inputs, outputs, effects, results, outcomes, impacts, etc., that enable such phenomena to be judged or measured. Both qualitative and quantitative indicators are needed for management learning, policy review, monitoring, and evaluation;
3. In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions, good or bad.

Invasive species
An introduced species that out-competes native species for space and resources.

Invertebrate
Animals without a backbone. In fishery management terms, refers to shellfish, including lobsters, clams, shrimps, oysters, crabs, and sea urchins.

Juvenile
A young fish or animal that has not reached sexual Maturity.

Landings
1. The number or poundage of fish unloaded by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the locations at which fish are brought to shore;
2. The part of the catch that is selected and kept during the sorting procedures on board vessels and successively discharged at dockside.

Landings Data
Information on the amount of fish caught and landed per Year.

Life Cycle
Successive series of changes through which an organism passes in the course of its development.

Lipofuscin
Brown-yellow pigmented granules that accumulate with age in certain tissues.

Management Authority
The legal entity that has been assigned by a state or states with a mandate to perform certain specified management functions in relation to a fishery, or an area (e.g. a coastal zone). Generally used to refer to a state authority, the term may also refer to an international management organization.

Management Strategy
The strategy adopted by the management authority to reach established management goals. In addition to the objectives, it includes choices regarding all or some of the following: access rights and allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations (e.g. calendar, closed areas, and seasons).

Marine
Waters that receive no freshwater input from the land and are substantially of full oceanic salinity (>30 practical salinity units (PSU) throughout the year).

Mature Individuals
The number of individuals known, estimated, or inferred to be capable of reproduction.

Maturity
Refers to the ability, on average, of fish of a given age or size to reproduce. Maturity information, in the form of percent mature by age or size, is often used to compute spawning potential.

Megalopae
The final larval stage found in decapod crustaceans.

Mesh Size
The size of holes in a fishing net. Minimum mesh sizes are often prescribed by regulations in order to avoid the capture of the young of valuable species before they have reached their optimal size for capture.

Migration
1. Systematic (as opposed to random) movement
of individuals of a stock from one place to another, often related to season. A knowledge of the migration patterns helps in targeting high concentrations of fish and managing shared stocks;
2. The movements of fish from feeding ground to spawning ground and back again, from nursery ground to feeding ground, and from spawning ground to nursery ground.

Model
In fisheries science, a description of something that cannot be observed. Often a set of equations and data used to make estimates.

Monitoring
1. To observe and record changes;
2. The collection of information for the purpose of assessment of the progress and success of a plan. Monitoring is used for the purpose of assessing performance of a management plan or compliance scheme and revising them, or to gather experience for future plans.

Mortality
Measures the rate of death of fi sh. Mortality occurs at all life stages of the population and tends to decrease with age. Death can be due to several factors such as pollution, starvation, and disease but the main source of death is predation (in unexploited stocks) and fishing (in exploited ones).

Mortality Rate
The rate at which the numbers in a population decrease with time due to various causes. Mortality rates are critical parameters in determining the effects of harvesting strategies on stocks, yields, revenues, etc. The proportion of the total stock (in numbers) dying each year is called the "annual mortality rate.

Native Species
A local species that has not been introduced.

Nearshore
Shallow waters at a small distance from the shore.

Non-Point Sources
Sources of sediment, nutrients, or contaminants that originate from many locations.

Nursery
That part of a fish's or animal's habitat where the young develop and grow.

Objective
Expresses the object of an action or what is intended to be achieved. Any objective will include explicit statements against which progress can be measured, and identify which things are truly important and the way they interrelate; quantified objectives are referred to as targets.

Overfished
1. An overfished stock or stock complex "whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding." A stock or stock complex is considered overfished when its population size falls below the minimum stock size threshold (MSST). A rebuilding plan is required for stocks that are deemed overfished
2. A stock is considered "overfished" when exploited beyond an explicit limit beyond which its abundance is considered 'too low' to ensure safe reproduction. In many fisheries fora the term is used when biomass has been estimated to be below a limit biological reference point that is used as the signpost defining an "overfished condition." This signpost is often taken as being FMSY, but the usage of the term may not always be consistent

Overfishing
1. According to the National Standard Guidelines, “overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis.” Overfishing is occurring if the maximum fishing mortality threshold (MFMT) is exceeded for 1 year or more;
2. In general, the action of exerting fishing pressure (fishing intensity) beyond the agreed optimum level. A reduction of fishing pressure would, in the medium term, lead to an increase in the total catch.

Parameter
A “constant” or numerical description of some property of a population (which may be real or imaginary).

Peeler
A hard shell crab in pre-molt stages.

Plankton
Floating organisms whose movements are more or less dependent on currents. While some zooplankton exhibit active swimming movements that aid in maintaining vertical position, plankton as a whole are unable to move against appreciable currents.

Pollution
1. The introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life; hazards to human health; hindrance to marine activities, including fishing and other legitimate uses of the sea; impairment of quality of sea water; and reduction of amenities;
2. Presence of substances and heat in environmental media (air, water, land) whose nature, location, or quantity produces undesirable environmental effects;
3. Activity that generates pollutants.

Population
The number of individuals of a particular species that live within a defined area.

Pots
Traps, designed to catch fish or crustaceans, in the form of cages or baskets of various materials (wood, wicker, metal rods, wire netting, etc.) and having one or more openings or entrances. Usually set on the bottom, with or without bait, singly or in rows, connected by ropes (buoy-lines) to buoys on the surface showing their position.

Predation
Relationship between two species of animals in which one (the predator) actively hunts and lives off the meat and other body parts of the other (the prey).

Primary Production
Assimilation (gross) or accumulation (net) of energy and nutrients by green plants and by organisms that use inorganic compounds as food.

Processing
The preparation or packaging of fish to render it suitable for human consumption, retail sale, industrial uses, or long-term storage, including but not limited to cooking, canning, smoking, salting, drying, filleting, freezing, or rendering into meal or oil, but not heading and gutting unless additional preparation is done.

Production
1. The total output especially of a commodity or an industry;
2. The total living matter (biomass) produced by a stock through growth and recruitment in a given unit of time (e.g. daily, annual production). The "net production" is the net amount of living matter added to the stock during the time period, after deduction of biomass losses through mortality;
3. The total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time.

Recruit
1. A young fish entering the exploitable stage of its life cycle;
2. A member of "the youngest age group which is considered to belong to the exploitable stock."

Recruitment (R)
1. The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year;
2. This term is also used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age 2 recruits.

Relative Abundance
Relative abundance is an estimate of actual or absolute abundance; usually stated as some kind of index; for example, as bottom trawl survey stratified mean catch per tow.

Removals
All of the fish "removed" from a stock by fishing, including the catch and any fish killed but not caught.

Resources
1. A natural source of wealth and revenue. Biological resources include genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use of value for humanity. Fishery resources are those resources of value to fisheries;
2. Anything that has value; living and nonliving components of nature such as fish, oil, water, and air.

Rulemaking
The process of developing Federal regulations which occurs in several steps, including publishing proposed rules in the Federal Register, accepting comments on the proposed rule, and publishing the final rule. An “advanced notice of proposed rulemaking” is published when dealing with especially important or controversial rules.

Salinity
The total mass of salts dissolved in seawater per unit mass of water; generally expressed in parts per thousands (ppt).

Sample
A proportion or a segment of a fish stock that is removed for study, and is assumed to be representative of the whole. The greater the effort, in terms of both numbers and magnitude of the samples, the greater the confidence that the information obtained is a true reflection of the status of a stock (level of abundance in terms of numbers or weight, age composition, etc.).

Seagrass
Rooted, grass-like flowering plants, such as eelgrass, that are adapted to live at sea, submersed, and can tolerate a saline environment.

Secondary Dispersal
A mechanism driving movement following initial settlement to benthic habitats often triggered by environmental or biological factors.

Shellfish
Shellfish include both mollusks, such as clams, and crustaceans, such as lobsters.

Spawning
Release of ova, fertilized or to be fertilized.

Spawning Stock
1. Mature part of a stock responsible for reproduction;
2. Strictly speaking, the part of an overall stock having reached sexual maturity and able to spawn. Often conventionally defined as the number or biomass of all individuals beyond “age at first maturity” or “size at first maturity”; that is, beyond the age or size class in which 50 percent of the individuals are mature.

Species
Group of animals or plants having common characteristics, able to breed together to produce fertile (capable of reproducing) offspring, and maintaining their “separateness” from other groups.

Stakeholder
1. A large group of individuals and groups of individuals (including governmental and non-governmental institutions, traditional communities, universities, research institutions, development agencies and banks, donors, etc.) with an interest or claim (whether stated or implied) that has the potential of being impacted by or having an impact on a given project and its objectives. Stakeholder groups that have a direct or indirect "stake" can be at the household, community, local, regional, national, or international level;
2. An actor having a stake or interest in a physical resource, ecosystem service, institution, or social system, or someone who is or may be affected by a public policy.

Stock
A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. A fish stock may be treated as a total or a spawning stock. Total stock refers to both juveniles and adults, either in numbers or by weight, while spawning stock refers to the numbers or weight of individuals that are old enough to reproduce.

Stock Assessment
The process of collecting and analyzing biological and statistical information to determine the changes in the abundance of fishery stocks in response to fishing, and, to the extent possible, to predict future trends of stock abundance. Stock assessments are based on resource surveys; knowledge of the habitat requirements, life history, and behavior of the species; the use of environmental indices to determine impacts on stocks; and catch statistics. Stock assessments are used as a basis to assess and specify the present and probable future condition of a fishery.

Subtidal
Permanently below the level of low tide, an underwater environment.

Sustainability
1. Ability to persist in the long-term. Often used as "short hand" for sustainable development;
2. Characteristic of resources that are managed so that the natural capital stock is non-declining through time, while production opportunities are maintained for the future.

Thresholds
1. Levels of environmental indicators beyond which a system undergoes significant changes; points at which stimuli provoke significant response;
2. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, and then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Tidal Marsh
Low, flat marshland traversed by channels and tidal hollows and subject to tidal inundation. Normally, the only vegetation present are salt-tolerant bushes and grasses.

Total Catch
Total catch (optimum yield, OY). The landed catch plus discard mortality.

Trawl Net
Towed net consisting of a cone-shaped body closed by a bag or codend and extended at the opening by wings. It can be towed by one or two boats and, according to the type, used on the bottom or in midwater (pelagic). In certain cases, as in trawling for shrimp or flatfish, the trawler can be specially rigged with outriggers to tow up to four trawls at the same time (double rigging)

Trawling
Fishing technique in which a net is dragged behind the vessel and retrieved when full of fi sh. This technique is used extensively in the harvest of pollock, cod, and other flatfish in North Pacific and New England fisheries. It includes bottom and midwater fishing activities.

Trotline
A heavy fishing line with baited hooks attached at intervals by means of branch lines.

Turbidity
The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.

Undersized
Fish (caught) at a size smaller than the minimum size limit established by regulation.

Value
1. Market and nonmarket values, gross and net values, and net benefits to consumers or goods and services;
2. The contribution of an action or object to user-specified goals, objectives, or conditions.

Water Column
The vertical column of seawater that extends from the surface to the bottom.

Water Quality
The chemical, physical, and biological characteristics of water in respect to its suitability for a particular purpose.

Water Resources
Water usable as inputs for economic production and livelihoods. A distinction is made between renewable and nonrenewable water resources. Nonrenewable water resources are not replenished at all or for a very long time by nature. This includes the so-called fossil waters. Renewable water resources are rechargeable due to the hydrological cycle unless they are overexploited, comprising groundwater aquifers and surface water like rivers and lakes.

APPENDIX 2. TABLE OF AMENDMENTS TO STATE PLAN

Amendments, revisions, information updates, and supplements to the Blue Crab FMP

Original FMP Adoption:	December 1998
Amendments:	Amendment 1 – December 2004 Amendment 2 – November 2013
Revisions:	May 2016
Supplements:	None
Information Updates:	None

APPENDIX 3. EXISTING PLANS, STATUTES, AND RULES

Existing Plans, Statutes, and Rules. This summary does not maintain exact language and should not be relied upon for legal purposes. See North Carolina General Statutes, North Carolina Administrative Code and Proclamations for exact language. The commission has the authority to delegate to the fisheries director the ability to issue public notices, called proclamations, suspending or implementing particular commission rules that may be affected by variable conditions. The proclamation authority granted to the fisheries director includes the ability to open and close seasons and fishing areas, set harvest and gear limits, and establish conditions governing various fishing activities. Proclamations are not included in this document because they change frequently.

Major General Statutes that apply to the blue crab fishery include but are not limited to:

- G.S.113-129. Definitions relating to resources.
    - Definitions in statute include fishing access areas, coastal fisheries, coastal fishing waters, crustaceans, fisheries resources, joint fishing waters, overfished, and overfishing.
- G.S.113-130. Definitions relating to activities of public.
    - Definitions in statute include resident, to buy, to fish, to sell, to take, and vessel.
- G.S.113-132. Jurisdiction of fisheries agencies.
    - Marine Fisheries Commission has jurisdiction over the conservation of marine and estuarine resources.
- G.S. 113-268 Injuring, destroying, stealing, or stealing from nets, seines, buoys, pots, etc
    - It is unlawful without authority of the owner to take fish from fishing gear; willfully, wantonly, and unnecessarily destroy gear; and willfully steal, destroy, or injure fishing gear.
- G.S.143B-289.52 Marine Fisheries Commission - Powers and Duties
    - Marine Fisheries Commission scope of power and duty which includes to approve Fishery Management Plans.

Major rules that apply to the blue crab fishery include but are not limited to:

- 15A NCAC 03I .0101 DEFINITIONS
    - Definitions in rule of what constitutes a blue crab shedding process and operation, peeler crab, and commercial fishing equipment or gear.
- 15A NCAC 03I .0105 LEAVING DEVICES UNATTENDED
    - It is unlawful to leave pots in coastal fishing waters for more than five consecutive days.
- 15A NCAC 03J .0104 TRAWL NETS
    - Proclamation authority is granted to the Fisheries Director to open areas described in 15A NCAC 03R .0106 to peeler crab trawling, defines mesh sizes for crab trawls, defines when it is permissible to take and possess blue crabs incidental to shrimp trawling, and sets forth limitations of incidental blue crab catch while shrimp trawling.
- 15A NCAC 03J .0301 POTS
    - The statewide pot cleanup period, closure periods, and the time and waterways restricted to pot usage are set in rule. Additionally, this rule sets forth gear identification criteria. The Fisheries Director is granted proclamation authority

over escape ring requirements including time, area, means and methods, season, and quantity.

- 15A NCAC 03J .0302 RECREATIONAL USE OF POTS
    - Recreational pots must be marked with a hot pink buoy and identifying information. Licensing requirements for recreational pots are included in this rule.
- 15A NCAC 03J .0303 DREDGES AND MECHANICAL METHODS PROHIBITED
    - The maximum weight of dredges, number of dredges, and time of day dredging and mechanical methods are allowed is set in rule.15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS
    - Cull tolerances, hard crab size limits, and peeler stage allowance are set under rule. The Fisheries Director is given proclamation authority to establish further restrictions upon the harvest of blue crabs.
- 15A NCAC 03L .0202 CRAB TRAWLING
    - By Fisheries Director proclamation areas and times may be specified to take or possess crabs by trawl. Mesh size of trawl gear is set in rule.
- 15A NCAC 03L .0203 CRAB DREDGING
    - The time and areas allowed for crab dredging are set in rule. The Fisheries Director, by proclamation authority, may further restrict the use of dredges to take blue crabs.
- 15A NCAC 03L .0204 CRAB POTS
    - The Fisheries Director, by proclamation authority, may require the use of terrapin excluder devices in crab pots while additionally imposing restrictions which specify areas, time periods, and means and methods.
- 15A NCAC 03L .0201 CRAB SPAWNING SANCTUARIES
    - The time period in which certain gears may not be set or used in crab spawning sanctuaries is set. The Fisheries Director may, by proclamation authority, designate additional areas and impose restrictions based on area, time, means and methods, and harvest limits.
- 15A NCAC 03R .0106 TRAWL NETS PROHIBITED
    - Trawl net prohibited areas referenced in 15A NCAC 03J .0104 are delineated.
- 15A NCAC 03R .0107 DESIGNATED POT AREAS
    - Pot areas referenced in 15A NCAC 03J .0301 are delineated.
- 15A NCAC 03R .0109 TAKING CRABS WITH DREDGES
    - The area referenced in 15A NCAC 03L .0203 is delineated.
- 15A NCAC 03R .0110 CRAB SPAWNING SANCTUARIES
    - The crab spawning sanctuaries within which the taking of crabs may be restricted or prohibited are described.

Major General Statute that apply to habitat protection include but are not limited to:

- G.S. 143B-279.8 Coastal Habitat Protection Plans
    - Lays out the process and purpose of creating the Coastal Habitat Protection Plans.
- G.S.143B-289.52 Marine Fisheries Commission - Powers and Duties
    - Marine Fisheries Commission scope of power and duty, which includes to approve Coastal Habitat Protection Plans and participation in developmental permit applications.

Major rules that apply to habitat protection include but are not limited to:

- 15A NCAC 03K .0204 Mechanical Methods Prohibited Areas
    - Prohibits the use of mechanical methods in mechanical methods prohibited areas to take oysters
- 15A NCAC 03K .0103 Shellfish Management Areas
    - The Fisheries Director may designate areas which the use of trawl nets, long haul seines, or swipe nets are prohibited.
- 15A NCAC 03N .0101 Fish Habitat Areas Scope and Purpose
    - Fish habitat areas are to establish and protect fragile estuarine and marine areas which support economically important populations.
- 15A NCAC 03N .0104 Prohibited Gear, Primary Nursery Areas
    - Prohibits use of trawl net, long haul seine, swipe net, dredge, or mechanical methods for clam or oysters in primary nursery areas
- 15A NCAC 03N .0105 Prohibited Gear, Secondary Nursery Areas
    - Prohibits use of trawl nets in permanent secondary nursery areas except select areas open by proclamation for shrimp or crab trawling.
- 15A NCAC 03R .0103 Primary Nursery Areas
    - Delineates boundaries of primary nursery areas.
- 15A NCAC 03R .0104 Permanent Secondary Nursery Areas
    - Delineates boundaries of permanent secondary Nursery Areas
- 15A NCAC 03K .0108 Dredges and Mechanical Methods Prohibited
    - Prohibits gears in areas of SAV, salt marsh, shellfish leases, Primary Nursery Areas, and designated Mechanical Methods Prohibited Areas

Table 3.1. East coast and Gulf of Mexico blue crab effort regulations by state as of May 2019.

	Harvest restrictions			
State	Season	Catch Limit	Time	Days
New Jersey	Delaware Bay Apr. 6 – Dec 4 Other Waters Mar. 15 – Nov. 30	None	Delaware Bay 4am-9pm Other Waters 24-hrs	None
Delaware	Mar. 1-Nov 30	None	1 hr. before sunrise-sunset	Sunday
Maryland	Males Apr. 1-Nov 16 Mature Female Apr. 1-Nov 10	Mature female	½ hr. before sunrise – 7 ½ hrs. after sunrise	Prohibited either Sun. or Mon.
Virginia	Mar. 17-Nov 30 Mature females prohibited Nov. 21-30	47 bushels Mar.17-Apr. 30 27 bushels May-Aug.	6am-2pm Mar.17-Apr. 30 5am-1pm May-Aug.	Mon.-Sat. except peeler pots
North Carolina	No pots Jan. 15-Feb. 7 May open areas cleared of pots	None	1 hr. before sunrise-1hr. after sunset	None
South Carolina	None	None	5am-9pm Apr. 1-Sept 15 6am-7pm Sept 15-Mar.31	None
Georgia	None	None	None	None
Florida	10 day closure for derelict trap removal	None	1 hr. before sunrise-1hr. after sunset	None
Alabama	Periodic derelict trap removal with no set closure period	None	1 hr. before sunrise-sunset	None
Mississippi	Possible 10-30 day closure for abandoned trap removal	None	½ hr. before sunrise – ½ hr. after sunset	None
Louisiana	Possible 14 day closure for abandoned trap removal	None	½ hr. before sunrise – ½ hr. after sunset	None
Texas	No pots 10-30 days in Feb.-Mar.	None	½ hr. before sunrise – ½ hr. after sunset	None

Table 3.2. East coast and Gulf of Mexico blue crab pot gear regulations by state as of May 2019.

State	Gear restrictions				
	Pots (max)	Escape Rings	Degradable Panels	Terrapin Excluders	Buoys
New Jersey	Delaware Bay 600 Other Waters 400	None	Yes	Some areas	Reflective I.D. Sink line
Delaware	200/vessel 500/vessel	None	None	None	I.D. Color coded
Maryland	50 up to 900/vessel w/ 2 crew	1 (2-3/16") 1 (2-5/16") May close for peelers	None	None But limited pot area	I.D.
Virginia	Chesapeake Bay 425 Tributaries and Potomac Tribs. in VA 255 Peeler 210	Seaside Eastern Shore 1 (2-3/16") 1 (2-5/16") Bay & Tribs. 2 (2-3/8")	None	None	I.D.
North Carolina	None Newport River only 150	3 (2-5/16")* May be closed in some areas	None	None	I.D. Sink line
South Carolina	None	2 (2-3/8")	None	None	I.D. With colors
Georgia	200 including peeler pots	2 (2-3/8")*	None	None	I.D. No green
Florida	Inshore 600 Offshore 400 Non-transfer 100 Peeler 400	3 (2-3/8")	Yes	None	I.D. Sink line
Alabama	None	2 (2-5/16") May be closed for peelers	None	None	I.D. ½ white Sink line
Mississippi	None	2 (2-3/8") Can be closed Apr.-Jun. Sept.-Oct.	None	None	I.D. or Color code
Louisiana	None	2 (2-5/16")* Can be closed Apr.-Jun. Sept.-Oct.	None	None	I.D. on metal trap tag/plastic bait cover Sink line
Texas	None	2 (2-3/8")	Yes	None	I.D. White gear tag

*Special placement required

Table 3.3. East coast and Gulf of Mexico blue crab life stage regulations by state as of May 2019.

	Size limits (inches)				
State	Hard	Soft	Peeler	Culling Tolerance	Sponge Crab Protection
New Jersey	4.75" 4.5" mature female	3.5"	3"	Zero	Prohibited
Delaware	5"	3.5"	3"	5% by number	Prohibited
Maryland	5" Apr. 1- July 14 5.25" July 15-Dec 15	3.5"	3.25" Apr. 1- July 14 3.5" July 15-Dec 15 Separated from catch	5 hard crabs/ bushel or 13/barrel 10 peelers	Prohibited to take but may sell from another state
Virginia	5"	3.5"	3.25" Mar. 17-Jul. 15 3.5" Jul. 16-Nov. 30	10 hard crabs/ bushel or 35/barrel 10 peelers/bushel or 5% in other containers	Prohibit brown/black sponge Bay wide Sanctuary at 35 ft. contour May 1-Sept. 15
North Carolina	5" Prohibit immature female	None	None Separated. White-lines no sale	5% by number/container	Prohibit brown/black sponge Spawning sanctuaries
South Carolina	5" Includes mature female	5" Includes mature female	None with peeler permit	Zero	Prohibited to take but may sell from another state
Georgia	5"	5"	3"	Zero	Prohibited to take but may sell from another state
Florida	5" Includes mature female	5"	None Separated from catch	5% by number/ container except bait	Prohibited
Alabama	5" Includes mature female Bait Dealer exempt	None Separate from catch	None Separated from catch	Zero except bait and work box	Prohibited May 26-Jan 14
Mississippi	5" Includes mature female	None	None	Zero	Prohibited Crab sanctuaries
Louisiana	5" Includes mature female Prohibit immature female	None	None Separated from catch	2% by number in 50 crab random sample	Prohibited Crab sanctuaries
Texas	5" Includes mature female	5"	5"	5% by number in separate container for bait only	Prohibited to take but may sell from another state

APPENDIX 4. ISSUE PAPERS
APPENDIX 4.1: ACHIEVING SUSTAINABLE HARVEST IN THE NORTH CAROLINA BLUE CRAB FISHERY

I. ISSUE

Implement management measures to achieve sustainable harvest in the North Carolina blue crab fishery.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF).

III. BACKGROUND

In North Carolina, fishermen have been harvesting blue crabs commercially since the 1800s, with the earliest documented landings reported in 1889 (1). Blue crab (*Callinectes sapidus*) is the most economically important species for commercial fisheries in North Carolina accounting for landings of 27.8 million pounds with an ex-vessel value of $26.9 million in 2016. North Carolina typically ranks within the top three blue crab producing states on the east coast both in pounds harvested and in value. North Carolina has historically accounted for approximately 22% of annual Atlantic coast blue crab landings since 1950.

The management strategy established in Amendment 1 to the Blue Crab FMP, adopted in 2004, used a single point estimate management trigger for stock status based on September data for mature female blue crabs from the Pamlico Sound Survey (P195; (2)). If the trigger was reached, then a seasonal 6.75-inch maximum size limit for mature females and a 5.25-inch minimum size limit for peeler crabs was enacted annually. Compliance and enforcement of the seasonal mature female maximum size limit and minimum size limit for peeler crabs was limited, hence they were largely ineffective at protecting large mature females. Even when crabbers complied with the management measure by releasing large females or undersize peelers, they may have been captured multiple times and injured, or ultimately harvested by another crabber during their migration to the lower estuaries and into the sounds.

Amendment 2 to the Blue Crab FMP adopted by the Marine Fisheries Commission in November 2013 incorporated the use of the traffic light stock assessment method and adaptive management measures for management of the blue crab stock (3). The Traffic Light method provided a more robust indicator of the overall blue crab stock condition because the data inputs were from multiple surveys encompassing all aspects of the blue crab's life history and distribution rather than a single point index. The 2016 revision to Amendment 2 implemented additional management measures due to exceeding a management threshold established in Amendment 2 (4). Those measures were:

- prohibit harvest of immature female hard crabs;
- prohibit harvest of dark sponge crabs from April 1 to April 30;
- prohibit targeted crab dredging;
- reduce the cull tolerance from 10% to 5%;

- require three cull rings in each crab pot; and
- require one cull ring to be placed within one full mesh of the corner and one full mesh of the bottom of the divider in the upper chamber of the pot.

As part of Amendment 3 a new stock assessment was conducted. A comprehensive stock assessment approach, the sex-specific two-stage model, was applied to available data to assess the status of North Carolina's blue crab stock during 1995–2016 (5). Data were available from commercial fishery monitoring programs and several fishery-independent surveys. The two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, and thus, provided a comprehensive assessment of blue crab status in North Carolina. The model estimated an overall declining trend in catch, relative abundance indices, population size of both male and female recruits and fully recruited crabs, with a rebound starting in 2007. The estimated fishing mortality remained high before 2007 and decreased by approximately 50% afterwards. The stock assessment only included hard blue crab harvest from the commercial fishery. Recreational harvest data was not included due to data limitations and commercial peeler and soft blue crab harvest data was not included due to them accounting for a small portion of the overall commercial landings and modelling limitations.

The stock status of North Carolina blue crab in the current stock assessment was determined based on maximum sustainable yield (MSY). Based on the results of this stock assessment, the North Carolina blue crab resource in 2016 was overfished with a 98%probability, given the average spawner abundance in 2016 was estimated at 50 million crabs (below the threshold estimate of 64 million crabs). Overfishing was also occurring in 2016 with a 52% probability, given the average fishing mortality in 2016 was estimated at 1.48 (above the fishing mortality threshold estimate of 1.46).

North Carolina General Statute 113-182.1 mandates that fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving a sustainable harvest and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute 113-129 as *"the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished"*.

In order to recover the blue crab stock, management options were developed to reduce fishing mortality (F) to end overfishing and rebuild the spawning stock and achieve sustainable harvest in the blue crab fishery (Table 4.1.1). A harvest reduction of 0.4% (in numbers of crabs) is projected to end overfishing within two years and a harvest reduction of 2.2% is projected to achieve sustainable harvest and rebuild the blue crab spawning stock within 10 years of the date of adoption of the plan with a 50% probability of success. This level of reduction is projected to bring spawning stock abundance to the threshold value of 64 million mature females.

Table 4.1.1. Catch reduction projections for varying levels of fishing mortality (*F*), based on 2016 data from the stock assessment, and the probability of achieving sustainable harvest within the 10-year rebuilding period defined in statute. The bolded row indicates the minimum requirement defined in statute.

F (yr -1)	Catch reduction (%)	Probability of achieving sustainable harvest within 10 years (%)	Comments
1.48	0	31	2016 average *F* from stock assessment
1.46	0.4	45	Catch reduction to meet *F* threshold and end overfishing
1.40	1.7	46	Catch reduction to meet spawner abundance threshold and end overfished status
1.38	**2.2**	**50**	**Catch reduction to meet minimum statutory requirement for achieving sustainable harvest**
1.30	3.8	67	
1.22	5.9	90	Catch reduction to meet *F* target
1.10	9.3	96	
1.00	12.3	100	
0.90	15.7	100	
0.80	19.8	100	Catch reduction to meet spawner abundance target
0.70	24.3	100	

There is also a need to update the adaptive management framework in the Blue Crab FMP. Amendment 2 established an adaptive management framework for blue crab management based on the annual update of the blue crab traffic light analysis (3). This framework requires annual updates of the blue crab traffic light analysis to be presented to the Marine Fisheries Commission as part of the annual Stock Overview report. If either the adult abundance or production characteristics of the traffic light are above 50% red for three consecutive years, then moderate management action (as defined in the framework; Table 4.1.2) is required. Additionally, if either the adult abundance or production characteristics is above 75% red for two years in a three-year period then elevated management action is required. The three-year period was chosen to prevent taking management action due to annual variability and to instead base any management response on a short but continued declining trend in the population. This framework was adopted in part due to the lack of a quantitative assessment of the blue crab stock. Now that a quantitative assessment has been completed and approved for management use (5) the adaptive management framework should be adjusted accordingly. The adaptive management framework will be adjusted for Amendment 3 to be based on updating the approved stock assessment model, not the traffic light approach.

Table 4.1.2. Management measures under the adaptive management framework for the blue crab Traffic Light in the North Carolina Blue Crab Fishery Management Plan Amendment 2.

Characteristic	Moderate management level	Elevated management level
Adult abundance	A1. Increase in minimum size limit for male and immature female crabs A2. Reduction in tolerance of sublegal size blue crabs (to a minimum of 5%) and/or implement gear modifications to reduce sublegal catch A3. Eliminate harvest of v-apron immature hard crab females	A4. Closure of the fishery (season and/or gear) A5. Reduction in tolerance of sublegal size blue crabs (to a minimum of 1%) and/or implement gear modifications to reduce sublegal catch A6. Time restrictions
Recruit abundance	R1. Establish a seasonal size limit on peeler crabs R2. Restrict trip level harvest of sponge crabs (tolerance, quantity, sponge color) R3. Close the crab spawning sanctuaries from September 1 to February 28 and may impose further restrictions	R4. Prohibit harvest of sponge crabs (all) and/or require sponge crab excluders in pots in specific areas R5. Expand existing and/or designate new crab spawning sanctuaries R6. Closure of the fishery (season and/or gear) R7. Gear modifications in the crab trawl fishery
Production	P1. Restrict trip level harvest of sponge crabs (tolerance, quantity, sponge color) P2. Minimum and/or maximum size limit for mature female crabs P3. Close the crab spawning sanctuaries from September 1 to February 28 and may impose further restrictions	P4. Prohibit harvest of sponge crabs (all) and/or require sponge crab excluders in pots for specific areas P5. Reduce peeler harvest (no white line peelers and/or peeler size limit) P6. Expand existing and/or designate new crab spawning sanctuaries P7. Closure of the fishery (season and/or gear)

IV. AUTHORITY

North Carolina General Statutes
113-134 RULES
113-182 REGULATION OF FISHING AND FISHERIES
113-182.1 FISHERY MANAGEMENT PLANS
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Commission Rules
15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS

V. DISCUSSION

Management measures specific to recreational harvest and commercial peeler and soft blue crab harvest were not included here because the harvest reductions needed relate specifically to the stock assessment and the commercial hard blue crab fishery. However, any approved management changes will affect all applicable sectors of the blue crab fishery. The discussion below includes specific management measures that were both quantifiable and projected to meet the harvest reduction for hard blue crabs, based on the terminal year of the stock assessment (2016), needed to end overfishing within two years and achieve sustainable harvest within 10 years with at least a 50% probability of success as outlined in North Carolina General Statute 113-182.1. Several management tools were explored to achieve sustainable harvest in the hard blue crab fishery. These include size limits, season and life stage closures, and reducing the cull tolerance of prohibited blue crabs, or some combination of these measures. Where possible, management impacts are presented by region (Figure 4.1.1). Data from the ocean were not included in this analysis as landings are minimal and often confidential.

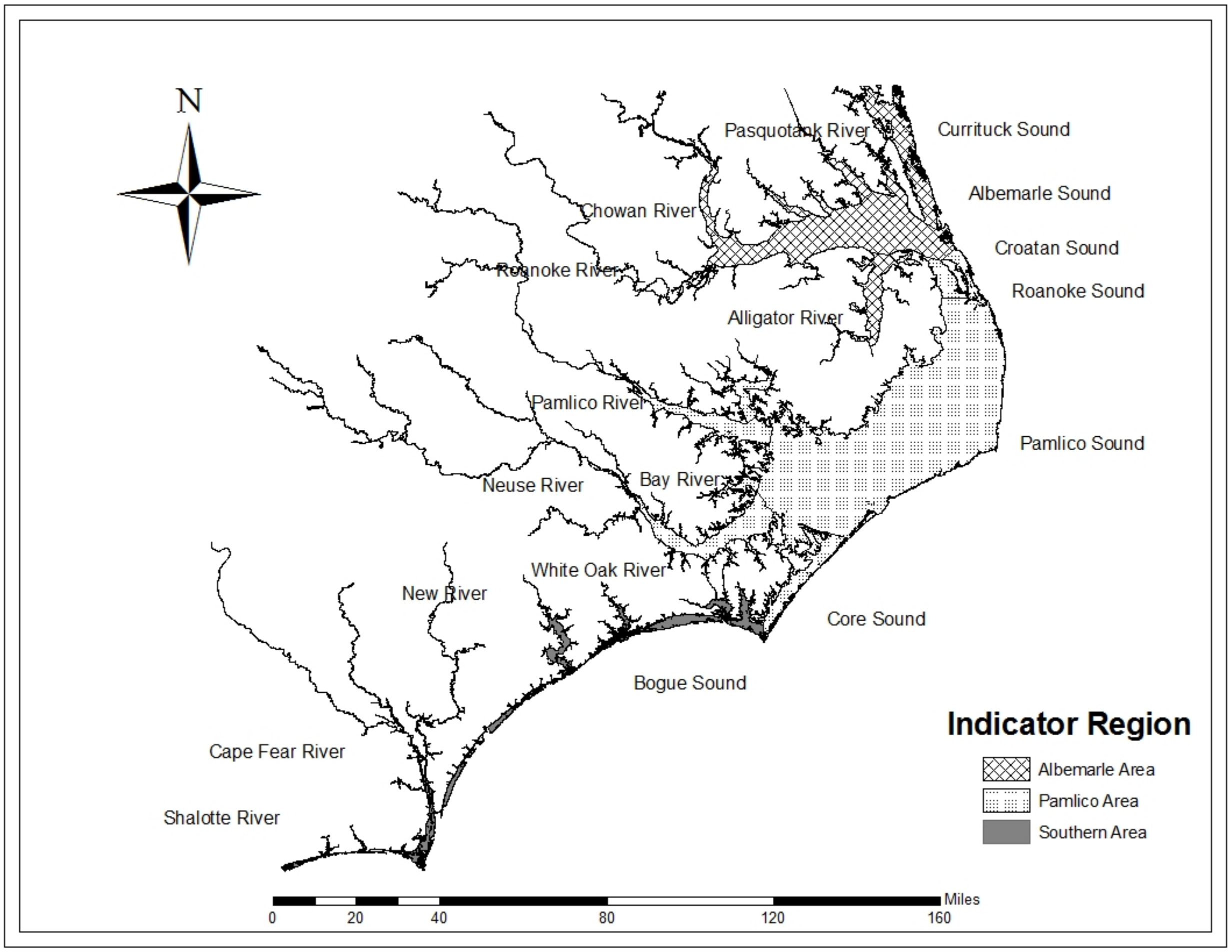

Figure 4.1.1. Map defining the spatial regions used in evaluating potential management impacts.

North Carolina General Statute 113-182.1 states the North Carolina Marine Fisheries Commission (NCMFC) can only recommend the General Assembly limit participation in a fishery if the commission determines sustainable harvest in the fishery cannot otherwise be achieved. Sustainable harvest can be achieved without the use of limited entry therefore limited entry is not considered an option at this time. The management options presented in this paper are a starting point for discussion on achieving sustainable harvest. Public input could provide additional options.

Trip limits, gear closures, and effort controls were not considered viable options for achieving sustainable harvest because they all allow for the possibility of recoupment by the fishery which prevents the accurate calculation of potential harvest reductions. While a trip limit could reduce the daily harvest of blue crabs it would be unlikely to reduce overall harvest unless trip limits were sufficiently low to make recoupment unlikely. Gear closures present the same issue of recoupment by the fishery where harvest from a closed gear may just be transferred to an open gear thereby providing little to no real harvest reduction. Effort controls, such as pot limits and fishing time restrictions, were not considered as recoupment is a concern with both approaches. A pot limit may not provide a real harvest reduction as blue crabs may potentially be caught in remaining pots in higher numbers, unless the limit was low enough to make gear saturation an issue which may be offset by simply fishing pots more frequently. Fishing time restrictions typically aim to limit the amount of gear that can reasonably be fished in a particular day but may be offset by increasing the number of crew aboard a vessel or fishing fewer pots more frequently. Some of these management options are explored in other issue papers such as the "Management Measures Beyond Quantifiable Harvest Reductions" issue paper, as they may provide some additional protections but their impact cannot be reasonably quantified.

Mature Female Size Limit

Size limits are a common management tool used to rebuild or protect the spawning stock of several species (e.g., striped bass, southern flounder, spotted seatrout). Mature females, peeler, and soft crabs are exempt from the 5-inch minimum size limit for hard crabs (NCMFC Rule 15A NCAC 03L .0201). The short-term effects of establishing a size limit for mature females would be reducing the pool of mature females available for harvest, which in turn would decrease the overall harvest. Decreasing the harvest of mature females should have an immediate effect on reducing the fishing mortality on mature female blue crabs. The benefit to the fishery of establishing a size limit for mature females would not be realized until the recruits produced survive to contribute to the population and the fishery. One of the major benefits to establishing a size limit for mature females is it would protect a portion of the spawning stock from harvest allowing them to remain in the population and the opportunity to release more clutches of eggs. Establishing a size limit for mature females could have a negative impact on the market by reducing the number of blue crabs available for purchase.

Establish a Maximum Size Limit for Mature Female Blue Crabs

Assuming no cull tolerance for mature female blue crabs, maximum size limit options were explored that fell within the range needed to attain sustainable harvest. From the analysis, most mature female blue crabs harvested are less than 6 inches' carapace width (CW). There were two maximum size limit options falling within the range needed for sustainable harvest, a 6.75-inch and 6.5-inch maximum size limit. The 6.75-inch CW maximum size limit would have an estimated 1.5% overall harvest reduction on average for 2016 which represents approximately 1.4% of the hard crab value (Table 4.1.3). The 6.5-inch CW maximum size limit would have an estimated 4.3% overall harvest reduction on average for 2016 which represents approximately

3.8% of the hard crab value (Table 4.1.4). Recoupment from either maximum size limit should not occur since once mature females reach either size they would be permanently protected from legal harvest.

Table 4.1.3. Harvest percentage (by number) and value of mature female blue crabs 6.75 inches CW and greater by area and overall, 2011-2017.

	Mature Female Harvest Percent >6.75" Carapace Width					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	0.6	0.9	0.1	1.6	244,793	1.4
2012	0.6	1.7	0.1	2.5	375,392	1.9
2013	2.1	0.5	<0.1	2.7	558,381	2.1
2014	1.8	1.3	0.1	3.2	901,165	3.0
2015	0.8	1.5	<0.1	2.4	587,445	2.0
2016	0.2	1.2	0.1	1.5	296,399	1.4
2017*	0.8	1.0	0.1	1.9	272,161	1.5
2011-2016 Average	1.0	1.2	0.1	2.3	493,929	2.0

*2017 shown for informational purposes only, not used in stock assessment.

Table 4.1.4. Harvest percentage (by number) and value of mature female blue crabs 6.5 inches CW and greater by area and overall, 2011-2017.

	Mature Female Harvest Percent >6.5" Carapace Width					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	1.6	2.3	0.3	4.2	627,286	3.5
2012	1.9	3.8	0.3	6.0	950,835	4.7
2013	4.7	1.5	0.2	6.4	1,355,304	5.1
2014	4.2	2.3	0.2	6.7	1,885,193	6.3
2015	1.9	3.3	0.1	5.4	1,334,084	4.5
2016	1.1	3.0	0.2	4.3	788,728	3.8
2017*	1.5	2.2	0.2	3.8	554,013	3.1
2011-2016 Average	2.5	2.7	0.2	5.4	1,156,905	4.8

*2017 shown for informational purposes only, not used in stock assessment.

Establish a Minimum Size Limit for Mature Female Blue Crabs

Assuming no cull tolerance for mature female blue crabs, minimum size limit options were explored that fell within the range needed to attain sustainable harvest. From the analysis, most mature female blue crabs harvested are less than 6 inches' CW. There were two minimum size limit options falling within the range needed for sustainable harvest, a 5-inch and 5.25-inch minimum size limit. The 5-inch CW minimum size limit would have an estimated 0.9% overall harvest reduction for 2016 which represents approximately 0.8% of the hard crab value (Table 4.1.5). The 5.25-inch CW minimum size limit would have an estimated 4.1% overall harvest reduction for 2016 which represents approximately 3.5% of the hard crab value over this same period (Table 4.1.6). Recoupment from either minimum size limit should not occur since once mature, females do not get any larger thus they would be permanently protected from legal harvest.

Table 4.1.5. Harvest percentage (by number) and value of mature female blue crabs less than 5 inches CW by area and overall, 2011-2017.

	Mature Female Harvest Percent <5" Carapace Width					Percent of Total
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Value
2011	0.0	1.2	0.0	1.2	155,675	0.9
2012	0.2	0.6	0.1	0.9	135,483	0.7
2013	0.2	0.9	0.3	1.4	328,168	1.2
2014	0.2	0.2	0.3	0.7	169,988	0.6
2015	0.1	0.1	0.1	0.3	72,376	0.2
2016	0.3	0.5	0.1	0.9	165,365	0.8
2017*	0.8	0.4	0.4	1.6	254,034	1.4
2011-2016 Average	0.2	0.6	0.1	0.9	171,176	0.7

*2017 shown for informational purposes only, not used in stock assessment.

Table 4.1.6. Harvest percentage (by number) and value of mature female blue crabs less than 5.25 inches CW by area and overall, 2011-2017.

	Mature Female Harvest Percent <5.25" Carapace Width					Percent of Total
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Value
2011	0.8	3.0	0.2	3.9	558,223	3.1
2012	0.9	1.7	0.3	2.9	451,630	2.2
2013	0.9	2.2	0.7	3.8	782,678	3.0
2014	0.5	0.6	0.8	1.8	468,715	1.6
2015	1.0	0.5	0.2	1.6	453,072	1.5
2016	1.4	2.2	0.4	4.1	726,198	3.5
2017*	1.9	1.4	0.9	4.2	639,781	3.6
2011-2016 Average	0.9	1.7	0.4	3.0	573,419	2.4

*2017 shown for informational purposes only, not used in stock assessment.

Life Stage and Season Closures

Closures to the blue crab fishery could include season, area, gear, or life stage. The premise behind this management tool is to restrict harvest, whether by time, location, fishery, or life stage to provide protection to blue crabs that are vulnerable to harvest in a particular place and time.

Prohibit Harvest of Immature Female Hard Crabs

Prohibiting the harvest of immature female hard crabs is an example of a life stage closure. In June 2016 the harvest of immature (v-apron) female blue crabs was prohibited under the conditions of the adaptive management framework in Amendment 2 (4; 5). The intent of this measure was to allow immature females the opportunity to mature before being subject to harvest. Data from 2016 was not used in calculating the average value because the prohibition occurred mid-way through the fishing year and would deflate the average reduction if it were included with years when the prohibition was not in effect. Data from 2017 (post-regulation change) was compared to 2011 through 2015 (pre-regulation change) to gauge the impact this regulation change had on commercial hard blue crab harvest after it was implemented. Some low level of harvest was expected in 2017 as immature females are included in the 5% cull tolerance for prohibited crabs in the blue crab catch. The calculations below assume the cull tolerance remains in place.

From 2011 to 2015, immature female crabs made up 1.2% of the total commercial hard blue crab harvest, this fell to 0.5% in 2016, and in 2017 immature female crabs accounted for 0.1% of the total commercial hard blue crab harvest (Table 4.1.7). Even with immature female hard crabs included in the 5% cull tolerance, prohibiting the harvest of immature female hard crabs appears to have increased the opportunity for more females to become spawning adults prior to being eligible for harvest when comparing 2017 harvest to previous years.

Table 4.1.7. Harvest percentage (percent by number) of immature female hard blue crabs by area and overall and annual value of the harvest, 2011 – 2017.

	Immature Female Harvest Percent					Percent
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	of Total Value
2011	0.7	0.5	0.0	1.2	132,871	0.7
2012	1.0	0.2	0.0	1.2	173,246	0.9
2013	1.2	0.1	0.0	1.3	245,834	0.9
2014	1.5	0.2	0.0	1.7	375,154	1.3
2015	0.6	0.3	0.0	0.9	203,234	0.7
2011-2015 Average	1.0	0.3	0.0	1.2	226,068	0.9
2016*	0.4	0.1	0.0	0.5	62,658	0.3
2017**	0.1	0.1	0.0	0.1	11,650	0.1

*2016 not used in average because prohibition on immature female harvest began in June 2016
**2017 shown for informational purposes only, not used in stock assessment

Season Closure

A season closure can be used to restrict harvest during certain times of the year to reduce removals from the stock. Since effort can be increased during the open periods of the fishery to offset losses during the closed season, it is best to have seasonal closures that are a minimum of two weeks, but preferably longer. The timing of harvest from the different blue crab fisheries should also be considered with any season closure.

Late season closures tend to be more effective in achieving harvest reductions because there is less opportunity for recoupment by the fisheries. However, a possible result of season closures would be an increase in discards, particularly in fisheries that land, but do not target blue crabs. Table 4.1.8 shows the monthly harvest percent by month, looking at this table shows, for example, a December closure has the potential to reduce commercial hard blue crab harvest by

2.9% for 2016 which represents approximately 2.8% of the hard blue crab value and a March closure has the potential to reduce commercial hard blue crab harvest by 5.0% and 6.6% of the annual value (Table 4.1.8).

At the request of the Blue Crab FMP AC, additional season closure options were explored for management options 12 and 18 in Table 4.1.13. These include various options for early season closures (portions or all of January, February, or March) as well as different early season closures based on area. If an early season closure is adopted, it would replace the annual pot closure period (Jan. 15 – Feb. 7 which may reopen after Jan. 19) and would remain closed for the entire closure period in order for the estimated harvest reduction to be achieved. Table 4.1.9 shows the estimated 2016 harvest reductions and value for the different early season closure periods explored. For example, one of the options explored is a March 1 through March 24 closure (examined because it is the same number of days as the current pot closure period) which would result in a 4.1% harvest reduction and accounts for 5.5% of the value of the 2016 hard blue crab harvest.

Table 4.1.8. Hard blue crab commercial harvest (percent weight) by region and month and December value by region, 2011 – 2017.

		Monthly Harvest Percent											
Year	Region	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2011	Albemarle	0.0	0.0	2.1	1.4	12.5	18.1	13.8	13.3	18.1	13.5	6.5	0.7
	Pamlico	0.2	0.7	6.7	8.9	13.4	15.4	15.3	10.9	12.9	8.7	5.1	1.8
	Southern	0.2	4.1	10.2	3.4	10.6	10.2	9.6	10.5	11.3	6.8	11.8	11.4
	Overall	0.1	0.6	4.5	4.7	12.8	16.5	14.2	12.1	15.6	11.1	6.2	1.7
2012	Albemarle	0.0	0.2	1.6	0.9	14.7	21.0	18.9	16.2	11.6	10.0	4.4	0.6
	Pamlico	0.3	1.1	5.4	9.7	19.7	19.4	16.0	11.6	6.5	5.9	3.3	1.3
	Southern	2.4	4.9	5.4	8.7	13.5	10.0	10.0	11.3	8.4	7.1	9.4	8.8
	Overall	0.3	0.8	3.0	4.1	16.1	19.7	17.4	14.4	9.9	8.5	4.5	1.4
2013	Albemarle	0.0	0.0	0.3	1.2	5.3	15.0	15.8	19.3	20.5	18.3	4.1	0.3
	Pamlico	0.1	0.1	1.5	8.6	14.5	17.0	14.6	12.6	10.2	11.4	7.7	1.7
	Southern	1.5	3.5	4.3	3.9	13.6	14.0	14.3	12.0	8.4	9.0	8.8	6.7
	Overall	0.2	0.3	0.9	3.1	8.0	15.4	15.4	17.2	17.3	16.0	5.3	1.1
2014	Albemarle	0.0	0.0	0.2	1.3	8.8	15.0	12.7	19.6	22.7	16.3	3.2	0.2
	Pamlico	0.2	0.4	0.9	7.0	11.0	13.3	15.8	16.3	15.4	13.2	5.1	1.4
	Southern	1.1	1.8	2.8	2.9	13.4	14.1	14.5	11.9	10.2	9.3	11.3	6.7
	Overall	0.1	0.2	0.5	2.6	9.6	14.6	13.5	18.4	20.4	15.2	4.0	0.9
2015	Albemarle	0.0	0.0	0.2	1.6	8.1	12.4	10.3	18.4	18.9	19.4	9.0	1.7
	Pamlico	0.2	0.1	1.2	4.2	7.2	13.1	16.8	15.3	12.9	11.7	11.4	5.9
	Southern	1.2	0.8	7.9	4.7	15.3	14.8	9.7	9.5	8.3	8.7	9.6	9.6
	Overall	0.1	0.1	0.9	2.6	8.2	12.7	12.4	17.0	16.4	16.4	9.8	3.4
2016	Albemarle	0.4	0.1	3.3	0.9	8.5	19.7	14.8	13.0	14.2	15.5	8.2	1.4
	Pamlico	1.5	0.4	6.8	3.7	9.0	11.2	13.7	13.3	11.7	13.2	11.0	4.4
	Southern	2.1	2.8	6.2	7.1	16.7	12.4	11.4	9.5	9.0	7.6	8.8	6.5
	Overall	1.0	0.4	5.0	2.4	9.2	15.8	14.1	12.9	12.9	14.0	9.4	2.9
2017*	Albemarle	0.2	0.6	0.9	0.8	16.6	22.5	11.7	13.6	13.3	14.8	4.9	0.2
	Pamlico	1.2	4.0	3.4	6.3	15.9	19.3	14.9	14.0	9.6	7.2	3.7	0.5
	Southern	3.0	7.3	3.6	5.2	13.7	11.3	10.2	10.4	8.6	9.2	10.1	7.2
	Overall	0.8	2.3	2.0	3.1	16.1	20.4	12.7	13.5	11.6	11.7	4.9	0.9
2011-2016	Albemarle	**0.1**	**0.1**	**1.2**	**1.2**	**9.6**	**16.6**	**14.2**	**16.9**	**17.9**	**15.6**	**5.9**	**0.8**
Average	Pamlico	**0.5**	**0.5**	**4.3**	**6.8**	**12.1**	**14.6**	**15.4**	**13.1**	**11.7**	**10.5**	**7.5**	**3.0**
	Southern	**1.4**	**3.1**	**6.2**	**5.3**	**13.8**	**12.4**	**11.5**	**10.8**	**9.2**	**8.0**	**9.9**	**8.3**
	Overall	**0.3**	**0.4**	**2.5**	**3.3**	**10.7**	**15.7**	**14.4**	**15.3**	**15.4**	**13.5**	**6.7**	**2.0**

*2017 shown for informational purposes only, not used in stock assessment

Table 4.1.9. Additional season closure options explored at the request of the Blue Crab FMP AC.

Closure Period	2016 Harvest Reduction (%)	2016 Value (%)
January 15 - February 7 Closure	0.1	0.2
January 1 - January 31 Closure	1.0	1.0
January 1 - February 28/29 Closure	1.3	1.6
March 1 - March 15 Closure	2.6	3.6
March 16 - March 31 Closure	2.4	3.1
March 1 - March 24 Closure	4.1	5.5
March 8 - March 31 Closure	4.3	5.7
March 1 - March 31 Closure	5.0	6.6
January 1 - January 31 Harvest Closure North of 58 Bridge	0.9	0.2
March 1 - March 15 Closure South of 58 Bridge	0.1	0.1
February 20 - March 15 Closure South of 58 Bridge	0.2	0.2

Adjust the Cull Tolerance of Prohibited Hard Blue Crabs

The current cull tolerance of 5% was implemented in June 2016 under the adaptive management plan in Amendment 2 through the May 2016 Revision (4), prior to this action the cull tolerance was 10%. If Amendment 3 is adopted without either maintaining the cull tolerance at 5% or adopting a different tolerance, then the cull tolerance will revert back to 10%. The harvest reductions for 2011-2015 are in relation to the 10% cull tolerance in place prior to 2016. The 2011-2015 period is included here for reference because if the adopted management strategy does not maintain the current 5% cull tolerance or set another cull tolerance value it will revert back to the 10% cull tolerance in place prior to the adoption of the 2016 Revision. Due to data limitations, low sample size, and fishermen behavior harvest reductions could only be calculated for lowering the cull tolerance to zero.

In order to avoid double counting crabs for the harvest reduction calculations and to properly calculate the harvest reduction from reducing the cull tolerance to zero, two different sets of calculations were produced. This was necessary because the cull tolerance (made up of immature females and sublegal males) and immature female harvest are intrinsically linked. Immature females less than five inches CW were previously included in the 10% cull tolerance and when immature female harvest was prohibited in 2016 they were included in the reduced 5% cull tolerance. As a result, the first set of calculations assumes the prohibition on immature female harvest is no longer in effect and immature females are once again subject to the 5-inch minimum size limit. The second set of calculations assumes the prohibition on immature female harvest remains in place and that reduction is accounted for with that management option.

Reducing the cull tolerance of prohibited hard blue crabs to zero (i.e., sublegal males and immature females) would allow individual crabs a greater chance to mature and spawn prior to being harvested. Assuming the prohibition on immature female harvest is removed and the 5-inch minimum size limit restored, the total harvest reduction from reducing the cull tolerance to zero would be 3.7% (combined for sublegal males and sublegal immature females) for 2016 which represents approximately 2.2% of the hard crab value (Table 4.1.10). Assuming the prohibition on immature female harvest remains in place, the total harvest reduction from reducing the cull tolerance to zero would be 3.6% for 2016 which represents approximately 2.2% of the hard crab value over this same period (Table 4.1.11). Recoupment would likely occur as males or immature females grow to the legal minimum size or as immature females mature.

Table 4.1.10. Harvest percentage (by number) and value of sublegal male and sublegal immature female hard blue crabs by area and overall, 2011-2017.

	Sublegal Male and Sublegal Immature Female Harvest Percent					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	3.7	1.1	0.1	4.9	502,626	2.8
2012	3.8	1.7	0.2	5.7	703,557	3.5
2013	2.1	0.4	0.1	2.7	470,373	1.8
2014	2.3	0.6	0.2	3.1	637,362	2.1
2015	2.7	1.2	0.1	4.0	728,081	2.5
2011-2015 Average	3.0	1.0	0.1	4.1	608,400	2.5
2016*	2.5	0.9	0.2	3.7	464,655	2.2
2017**	3.1	0.5	0.1	3.8	467,038	2.6

*2016 not used in average because prohibition on immature female harvest and reduction in cull tolerance began halfway through the year

**2017 shown for informational purposes only, not used in stock assessment

Table 4.1.11. Harvest percentage (by number) and value of sublegal male and immature female (2017 only) hard blue crabs by area and overall, 2011-2017.

	Sublegal Male Harvest Percent					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	3.5	0.9	0.1	4.5	465,443	2.6
2012	3.5	1.6	0.2	5.3	639,218	3.2
2013	1.8	0.4	0.1	2.3	401,069	1.5
2014	2.2	0.5	0.2	2.8	564,363	1.9
2015	2.5	1.1	0.1	3.8	686,496	2.3
2016*	2.5	0.9	0.2	3.6	452,896	2.2
2017**	3.1	0.5	0.1	3.7	462,804	2.6
2011-2015 Average	2.8	0.9	0.1	3.8	534,914	2.2
2017 Immature Female Harvest	0.1	0.1	0.0	0.1	11,650	0.1

*2016 not used in average because prohibition on immature female harvest and reduction in cull tolerance began halfway through the year

**2017 shown for informational purposes only, not used in stock assessment

Harvest Reduction Scenarios

The individual estimated 2016 harvest reduction for each management measure examined are presented in Table 4.1.12. They range from 0.5% (prohibit immature female harvest) to 5.0% (March 1 through March 31 closure). Cumulative reductions for combinations of management measures were calculated using the 2016 reduction from each separate measure as inputs into the appropriate formula for the number of options being combined (Table 4.1.13). Potential management scenario combinations are presented in Tables 4.1.14-4.1.15. They range from implementing one to four of the above management measures and cover all possible combinations of measures explored in this paper. The projected 2016 reductions range from 0.5% to 10.9% depending on the combination of management options. The minimum harvest reduction required to satisfy statutory requirements is 2.2% and can be achieved by implementing a 5.0-inch mature female minimum size limit, prohibiting immature female hard crab harvest, and January 1 through January 31 closure (2.3% reduction). Table 4.1.15 expands on possible closure dates for management scenarios 12 and 18 from Table 4.1.14. Due to the low likelihood they would be selected together, management measure combinations with both a minimum and maximum size limit for mature female blue crabs or multiple closure periods are not presented in Table 4.1.13 but can be produced upon request.

Table 4.1.12. Estimated individual 2016 harvest and value reduction for each management measure.

Management Measure	Estimated 2016 Harvest Reduction (%)	Estimated 2016 Value Reduction (%)
6.75" Mature Female Maximum Size	1.5	1.4
6.5" Mature Female Maximum Size	4.3	3.8
5.0” Mature Female Minimum Size	0.9	0.8
5.25” Mature Female Minimum Size	4.1	3.5
Prohibit Immature Female Harvest	0.5	0.3
December 1 - December 31 Closure	2.9	2.8
Reducing Cull Tolerance to Zero	3.7	2.2
January 15 - February 7 Closure	0.1	0.2
January 1 - January 31 Closure	1.0	1.0
January 1 - February 28/29 Closure	1.3	1.6
March 1 - March 15 Closure	2.6	3.6
March 16 - March 31 Closure	2.4	3.1
March 1 - March 24 Closure	4.1	5.5
March 8 - March 31 Closure	4.3	5.7
March 1 - March 31 Closure	5.0	6.6

Table 4.1.13. Cumulative harvest reduction equations for each number of management options considered.

Number of Options	Harvest Reduction Equation	Variable Definition
1	Z=X	Z=cumulative harvest reduction
2	Z=X+((1-X)*Y)	X=reduction from option 1
3	Z=X+((1-X)*Y)+(1-(X+((1-X)*Y)))*W	Y=reduction from option 2
4	Z=X+((1-X)*Y)+((1-(X+((1-X)*Y)))*W)+((1-(X+((1-X)*Y)+(1-(X+((1-X)*Y)))*W))*U)	W=reduction from option 3
		U=reduction from option 4

Table 4.1.14. Estimated harvest reductions for all management scenario combinations. Gray boxes indicate the harvest reduction needed for varying probabilities of achieving sustainable harvest. Options 1 through 5 do not meet statutory requirements for achieving sustainable harvest. Beginning with option 6, all remaining options meet or exceed the minimum statutory requirement for achieving sustainable harvest. *Examples of different season closures for options 12 and 18 can be found in Table 4.1.15.

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
Options 1-5: Do not meet required 50% probability of ending overfished			
1	Prohibit Immature Female Harvest	1.1	0.5
2	5" Mature Female Minimum Size	0.9	0.9
3	5" Mature Female Minimum Size Prohibit Immature Female Harvest	2.0	1.4
4	6.75" Mature Female Maximum Size	2.3	1.5
5	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest	3.4	2.0
Reduction with a 50% probability of ending overfished			2.2
6	December Closure	2.0	2.9
7	Prohibit Immature Female Harvest December Closure	3.1	3.4
8	Reducing Cull Tolerance to Zero	4.1	3.7
Reduction with a 67% probability of ending overfished			3.8
9	5" Mature Female Minimum Size December Closure	2.9	3.8
10	Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	5.1	4.1
11	5.25" Mature Female Minimum Size	3.0	4.1
12*	5" Mature Female Minimum Size Prohibit Immature Female Harvest December Closure	4.0	4.3
13	6.5" Mature Female Maximum Size	5.4	4.3
14	6.75" Mature Female Maximum Size December Closure	4.3	4.4
15	5" Mature Female Minimum Size Reducing Cull Tolerance to Zero	5.0	4.6
16	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest	4.1	4.6
17	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest	6.4	4.8
18*	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest December Closure	5.3	4.8
19	5" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	5.9	4.9
20	6.75" Mature Female Maximum Size Reducing Cull Tolerance to Zero	6.3	5.1
21	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	7.2	5.5
Reduction with a 90% probability of ending overfished			5.9
22	Reducing Cull Tolerance to Zero December Closure	6.0	6.5

Table 4.1.14. continued…

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
23	Prohibit Immature Female Harvest December Closure Reducing Cull Tolerance to Zero	7.0	6.9
24	5.25" Mature Female Minimum Size December Closure	4.9	6.9
25	6.5" Mature Female Maximum Size December Closure	7.3	7.1
26	5" Mature Female Minimum Size December Closure Reducing Cull Tolerance to Zero	6.9	7.3
27	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest December Closure	6.0	7.3
28	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest December Closure	8.3	7.5
29	5.25" Mature Female Minimum Size Reducing Cull Tolerance to Zero	7.0	7.6
30	5" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	7.8	7.7
31	6.5" Mature Female Maximum Size Reducing Cull Tolerance to Zero	9.3	7.8
32	6.75" Mature Female Maximum Size December Closure Reducing Cull Tolerance to Zero	8.2	7.9
33	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	7.9	8.0
34	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	10.2	8.2
35	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	9.1	8.3
Reduction with a 96% probability of ending overfished			9.3
36	5.25" Mature Female Minimum Size December Closure Reducing Cull Tolerance to Zero	8.8	10.3
37	6.5" Mature Female Maximum Size December Closure Reducing Cull Tolerance to Zero	11.1	10.5
38	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	9.7	10.7
39	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	12.0	10.9

Table 4.1.15. Estimated harvest reductions for management options 12 and 18 from Table 4.1.14 with various closure periods requested by the Blue Crab FMP AC.

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
Option 12.1: Does not meet required 50% probability of ending overfished			
12.1	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 15 - February 7 Closure	2.2	1.5
Reduction with a 50% probability of ending overfished			2.2
12.2	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 1 - January 31 Closure	2.4	2.3
12.3	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 1 - February 28/29 Closure	2.9	2.7
12.4	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 16 - March 31 Closure	3.4	3.7
Reduction with a 67% probability of ending overfished			3.8
12.5	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 15 Closure	3.2	4.0
12.6	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 24 Closure	4.1	5.4
12.7	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 8 - March 31 Closure	4.2	5.6
Reduction with a 90% probability of ending overfished			5.9
12.8	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 31 Closure	4.6	6.3

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
Option 18.1: Does not meet required 50% probability of ending overfished			
18.1	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 15 - February 7 Closure	3.5	2.1
Reduction with a 50% probability of ending overfished			2.2
18.2	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 1 - January 31 Closure	3.7	2.9
18.3 (BCAC)	Prohibit Immature Female Harvest Jan. 1 - Jan. 31 Closure North of Hwy 58 Bridge March 1 - March 15 Closure South of Hwy 58 Bridge 6.75" Mature Female Max. Size North of Hwy 58 Bridge	3.7	3.2
18.4	Prohibit Immature Female Harvest Jan. 1 - Jan. 31 Closure North of Hwy 58 Bridge Feb. 20 - March 15 Closure South of Hwy 58 Bridge 6.75" Mature Female Max. Size North of Hwy 58 Bridge	3.8	3.2
18.5	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 1 - February 28/29 Closure	4.2	3.3
Reduction with a 67% probability of ending overfished			3.8
18.6	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 16 - March 31 Closure	4.7	4.3
18.7	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 15 Closure	4.6	4.5
Reduction with a 90% probability of ending overfished			5.9
18.8	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 24 Closure	5.4	6.0
18.9	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 8 - March 31 Closure	5.5	6.2
18.10	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 31 Closure	5.9	6.9

Adaptive Management of the North Carolina Blue Crab Stock

Adaptive management is a structured, iterative process of decision-making when uncertainty is present, with the objective of reducing uncertainty through time with monitoring. Adaptive management uses a learning process to improve management outcomes (6). The challenge with using adaptive management is to find a balance between gaining knowledge to improve management and achieving the best outcome based on current knowledge (7). As more is learned about a fishery, adaptive management provides flexibility to incorporate new data and information to accommodate alternative and/or additional actions. In the context of North Carolina FMPs, adaptive management is an optional management framework that allows for specific management changes to be taken between FMP reviews under specified circumstances to accomplish the goals and objectives of the plan. Proposed adaptive management actions are evaluated, adopted, and documented through an issue paper and the final revision document. The revision document and process is comparable to the federal "addendum" process.

Amendment 2 established an adaptive management framework for blue crab management based on the annual update of the blue crab traffic light analysis (3). Amendment 3 replaced this framework with one based on the peer-reviewed and approved stock assessment model developed by division staff for the North Carolina blue crab stock. The stock assessment was able to establish biological reference points necessary for managing and ensuring the sustainable harvest of the blue crab stock. A harvest reduction of 0.4% (in numbers of crabs) is projected to end overfishing within two years and a harvest reduction of 2.2% (in numbers of crabs) is projected to achieve sustainable harvest and rebuild the blue crab spawning stock within 10 years of the date of adoption of the plan with a 50% probability of success. This level of reduction is projected to bring spawning stock abundance to the threshold value of 64 million mature females.

The adaptive management framework upon approval of Amendment 3 shall consist of the following:

1. Update the stock assessment at least once in between full reviews of the FMP, timing at the discretion of the division
    a. If the stock is overfished and/or overfishing is occurring or it is not projected to meet the sustainability requirements, then management measures shall be adjusted using the director's proclamation authority
    b. If the stock is not overfished and overfishing is not occurring, then management measures may be relaxed provided it will not jeopardize the sustainability of the blue crab stock
2. Any quantifiable management measure, including those not explored in this paper, with the ability to achieve sustainable harvest (as defined in the stock assessment), either on its own or in combination, may be considered
3. Use of the director's proclamation authority for adaptive management is contingent on:
    a. consultation with the Northern, Southern, and Shellfish/Crustacean advisory committees
    b. approval by the Marine Fisheries Commission

Upon evaluation by the division, if a management measure adopted to achieve sustainable harvest (either through Amendment 3 or a subsequent Revision) is not working as intended, then it may be revisited and either: 1) revised or 2) removed and replaced as needed provided it conforms to steps 2 and 3 above.

VI. MANAGEMENT OPTIONS

(+ Potential positive impact of action)
(- Potential negative impact of action)

Below are overarching positive and negative impacts for all options, specific impacts from an option may be found below that option.

- \+ May increase abundance of mature females helping to rebuild the spawning stock
- \+ Will affect both commercial and recreational blue crab fisheries
- \+ No rule changes required
- – Decreased harvest with economic loss to the fishery

1. Implement a size limit for the harvest of mature female blue crabs
   - \+ May increase juvenile recruitment
   - – Some regions may be impacted more than others
   - – Increased catch processing time for fishermen
     - a. 6.75-inch maximum size limit for mature female blue crabs
     - b. 6.5-inch maximum size limit for mature female blue crabs
     - c. 5.0-inch minimum size limit for mature female blue crabs
     - d. 5.25-inch minimum size limit for mature female blue crabs

2. Limit the harvest of immature female hard blue crabs
   - – Some regions may be impacted more than others
   - – Predicted reduction may be less than expected due to recoupment once immature female crabs mature or they may be legally harvested as peeler or soft crabs
   - – Increased catch processing time for fishermen
     - a. Maintain current prohibition on immature female hard blue crab harvest (in effect through 2016 Revision to Amendment 2)
     - b. Allow harvest of immature female hard blue crabs with a 5-inch minimum size limit

3. Seasonal closure of the blue crab fishery
   - +/- Depending on the timing, the predicted reduction may be less than expected due to recoupment once the fishery reopens

4. Adjust the cull tolerance for prohibited blue crabs
   - \+ Increases escapement of prohibited crabs
   - – Predicted reduction may be less than expected due to recoupment once crabs reach legal size or stage

- – Increased catch processing time for fishermen
    a. Maintain the current cull tolerance of 5% (in effect through 2016 Revision to Amendment 2)
    b. Reduce the cull tolerance to zero

5. Adopt the adaptive management framework based on the peer-reviewed and approved stock assessment model
    - + Management is based on biological reference points
    - + Provides for the protection and future sustainability of the blue crab stock
    - – Potential uncertainty in regulations for public

VII. RECOMMENDATIONS

<u>NCMFC Selected Management Strategy</u>

- A closed season where both regions will remain closed for the entirety [replaced the variable pot closure period(s) prior to Amendment 3]
    - Jan. 1 - 31 north of the Highway 58 bridge
    - March 1 - 15 south of the Highway 58 bridge
- A 5-inch minimum size limit for mature female crabs statewide; [replaced the NCMFC's November 2019 preferred management option of a 6.75-inch maximum size limit for mature females north of the Highway 58 bridge to Emerald Isle]
- Retain the prohibition on harvest of immature female hard crabs statewide
- Retain the current 5% cull tolerance, established in the 2016 Revision
- Adopt proposed adaptive management framework
    - Update the stock assessment at least once between full reviews of the FMP, timing at the discretion of the division
        a. If the stock is overfished and/or overfishing is occurring or the blue crab stock is not projected to meet the sustainability requirement, management measures shall be adjusted using the director's proclamation authority
        b. If the stock is not overfished and/or overfishing is not occurring management measures may be relaxed provided it will not jeopardize the sustainability of the blue crab stock
    - Any quantifiable management measure, including those not explored in this paper, with the ability to achieve sustainable harvest (as defined in the stock assessment), either on its own or in combination, may be considered

NCMFC Summary
In order to recover the blue crab stock, harvest reduction of 0.4% (in numbers of crabs compared to 2016 numbers) was projected to end overfishing within two years and a harvest reduction of 2.2% was projected to achieve sustainable harvest and rebuild the blue crab spawning stock within 10 years of the date of adoption of the plan with a 50% probability of success.

After committee recommendations and public comment, the NCMFC selected a preferred management strategy at their November 2019 meeting. The preferred management strategy at the time included:

- Option 18.3 (Table 4.1.15)
    - North of the Highway 58 Bridge: January 1 through January 31 closed season, 6.75” mature female hard crab maximum size limit, and prohibit immature female hard crab harvest
    - South of the Highway 58 Bridge: March 1 through March 15 closed season and prohibit immature female hard crab harvest
    - Replace the current pot closure period and remain closed in entirety
    - Maintain the 5% cull tolerance established in the 2016 Revision to Amendment 2
- Adopt proposed adaptive management framework and allow measures to be relaxed if the assessment update indicated the stock was not overfished and overfishing was not occurring and recommend updating the stock assessment once 2019 data is available.

It was estimated this recommendation would result in a 3.7% harvest reduction with a 50% - 67% probability of success.

After legislative review, the NCMFC voted on a selected management strategy at their February 2020 meeting. Commissioners discussed a perceived inequity between crabbers in the north and south due to the preferred management strategy from November 2019, including a maximum size limit on mature females for only the northern part of the state. To address this inequity, **the commission shifted their recommendation to a 5-inch minimum size limit for mature female crabs statewide rather than the maximum size limit on mature females in the northern region of the state. The selected management strategy was estimated to result in a 2.4% reduction with a 50% probability of success.** Additionally, after consideration of the burden updating the stock assessment would put on division stock assessment staff and understanding that the stock assessment would be updated through the new adaptive management framework, **the NCMFC removed their recommendation to update the stock assessment with data through 2019**. Initial May 1, 2020 implementation of the adopted measures is found in Proclamation M-8-2020.

See Appendix 4.7 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Blue Crab FMP Amendment 3.

VIII. LITERATURE CITED

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6. Holling, C. S. (editor). 1978. *Adaptive Environmental Assessment and Management*. John Wiley and Sons. London, England.
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APPENDIX 4.2: MANAGEMENT OPTIONS BEYOND QUANTIFIABLE HARVEST REDUCTIONS

I. ISSUE

Results of qualitative management on the North Carolina blue crab stock cannot be quantified. However, implementing these management measures may serve to improve the overall blue crab stock and reduce bycatch.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF).

III. BACKGROUND

As part of Amendment 3, a comprehensive stock assessment was completed. A sex-specific two-stage model was applied to available data to assess the status of North Carolina's blue crab stock during 1995–2016 (1). Data were available from commercial fishery monitoring programs and several fishery-independent surveys. The two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, providing a comprehensive assessment of blue crab status in North Carolina. The model estimated an overall declining trend in catch, relative abundance, population size of both male and female recruits and fully recruited crabs, with a rebound starting in 2007. The estimated fishing mortality remained high before 2007 and decreased by approximately 50% afterwards.

The stock status of North Carolina blue crab in the current stock assessment was determined based on maximum sustainable yield (MSY). Results of this stock assessment indicate the North Carolina blue crab resource in 2016 was overfished with a probability of 0.98, with the average spawner abundance in 2016 estimated at 50 million crabs (below the threshold estimate of 64 million crabs). Overfishing was also occurring in 2016 with a probability of 0.52. The average fishing mortality in 2016 was estimated at 1.48, above the fishing mortality threshold estimate of 1.46.

To increase blue crab spawners and recruitment, qualitative management options were developed. Impact of these measures on recruitment and overfishing cannot always be directly measured from the results of the stock assessment. These qualitative management measures may impact these metrics, however, the magnitude of these management measures as well as the possible response of the stock is unknown.

As previously noted, the 2016 stock assessment set quantifiable values for blue crab fishing mortality (overfishing) and spawning stock biomass (overfished). Projections were performed to demonstrate how changes in fishing mortality would impact spawning stock biomass. The earlier traffic light was not a modeling approach that produces these important biological reference points and therefore all management measures considered at that time were not required to be quantitatively assessed in the same manner as required now via the 2016 stock assessment. Currently there are two categories of management measures: quantifiable and beyond quantifiable. “Quantifiable” are those used as direct data inputs for the stock assessment model and produce weighable impact on blue crab recruitment or mortality. “Beyond Quantifiable” are those that aren’t directly part of the stock assessment model and there is no way to measure the impact to the modelled fishing mortality. This does not mean that beyond quantifiable measures are not important to consider in management, they merely are not able to be included in the percent reduction needed to end overfishing/overfished status as statutorily required. If beyond quantifiable measures are implemented, future stock assessments will indirectly reflect their effect on the fishery status. Various beyond quantifiable management options under consideration include gear modifications, life stage closures, and means to control effort in the fishery. Since specific impacts on recruitment and overfishing cannot be calculated, relevant empirical data for the various option are presented herein.

IV. AUTHORITY

North Carolina General Statutes
113-134 RULES
113-182 REGULATION OF FISHING AND FISHERIES
113-182.1 FISHERY MANAGEMENT PLANS
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Rules
15A NCAC 03J .0301 POTS
15A NCAC 03J .0302 RECREATIONAL USE OF POTS
15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS
15A NCAC 03L .0202 CRAB TRAWLING
15A NCAC 03L .0204 CRAB POTS
15A NCAC 03R .0118 EXEMPTED CRAB POT ESCAPE RING AREAS

V. DISCUSSION

Gear Modifications

Modification to harvest gear can be used to reduce catch and mortality of sublegal bycatch of target and non-target species. Several studies have examined the effects of the number, placement, and size of cull rings in crab pots. Sampling is also conducted year-round and statewide at commercial crab houses by NCDMF to characterize the gears and harvest of the commercial trip. This sampling is opportunistic and may not characterize the variations in the gear used in the fishery precisely, and sampling intensity can vary by area and year.

Cull ring size

Cull (escape) rings are a device used in crab pots to reduce bycatch, reduce sublegal harvest, and reduce cull time for fishermen. Current rules require three cull rings per pot of 2 5/16-inches minimum inside diameter, one of which must be placed within one full mesh of the corner and one full mesh of the bottom of the divider in the upper chamber of the pot. Size of cull rings required vary among other states (Appendix 3).

Rudershausen and Turano (2) tested three different size cull rings: 2 5/16-inches, 2 3/8-inches, and 2 7/16-inches. The study indicated catch rates of sublegal males were reduced by increasing cull ring size and not by the number of rings (Table 4.2.1). They also found the catch rates of legal males and mature females were generally maintained with larger cull rings and estimated the body length of minimally legal male crabs was not less than the current minimum cull ring diameter. Rudershausen and Hightower (3) tested three different size cull rings: 2 5/16-inches, 2 3/8-inches, and 2 7/16-inches from May through September 2010 in the Pamlico River. Parameters estimated included the carapace width at which half the individuals are retained pots and the carapace width at initial retention. They found the mean number of legal male crabs was not significantly different among cull ring sizes, but the mean number of sublegal male crabs was significantly less in pots using the two largest cull ring sizes (Table 4.2.2). The credible limits in Table 4.2.2 indicate the range of values within which an unobserved parameter of a predictive distribution falls. For instance, a 2 5/16-inch cull ring initial retention would fall in the carapace width range of 4.59 inches to 4.73 inches with a median carapace width of 4.67 inches.

Table 4.2.1. Effects of cull ring size, number of cull rings, and their interactions on the CPUE of blue crabs. An asterisk next to the *F*-value indicates data transformation (2).

			Legal male		Sublegal male		Mature female		Sponge	
Estuary	Effect	df	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Currituck Sound	Ring Size	2	10.62	<0.001	523*	<0.001	3.52*	0.030		
	Ring number	2	8.25	<0.001	11.1*	<0.001	1.28*	0.277		
	Interaction	4	0.87	0.482	0.39*	0.816	0.66*	0.623		
Core Sound	Ring Size	2	1.08	0.340	195*	<0.001	10.2*	<0.001		
	Ring number	2	1.39	0.250	2.41*	0.090	0.42*	0.657		
	Interaction	4	0.30	0.878	0.22*	0.928	0.93*	0.449		
Albemarle Sound	Ring Size	1	0.03*	0.864	83.8*	<0.001	0.82*	0.365		
	Ring number	2	0.34*	0.712	3.27*	0.038	0.004*	0.996		
	Interaction	2	0.27*	0.762	0.41*	0.661	0.07*	0.929		
Bogue Sound	Ring Size	1	0.46	0.498	272*	<0.001	2.47*	0.116		
	Ring number	2	1.14	0.319	1.79*	0.168	0.90*	0.406		
	Interaction	2	0.02	0.983	0.01*	0.990	1.17*	0.310		
Eastern Pamlico Sound	Ring Size	1	1.11	0.292	0.61*	0.433	3.16*	0.076	0.04*	0.849
	Ring number	2	0.76	0.469	1.59*	0.204	1.08*	0.341	0.08*	0.920
	Interaction	2	0.46	0.630	0.16*	0.851	0.03*	0.972	0.12*	0.884
Cape Fear River	Ring Size	1	0.02	0.894	15.7*	<0.001	0.002*	0.962		
	Ring number	2	0.19	0.826	2.91*	0.055	0.005*	0.995		
	Interaction	2	2.82	0.060	0.56*	0.572	0.523*	0.593		
Pamlico River	Ring Size	1	2.99	0.084	29.0*	<0.001	3.44*	0.064		
	Ring number	2	0.95	0.388	1.47*	0.230	0.74*	0.479		
	Interaction	2	0.25	0.782	1.62*	0.197	0.37*	0.688		

Table 4.2.2. Median and credible limits (CLs) of logistic retention model parameter estimates of the carapace width (inches) retention size (at which half the individuals are retained pots) and initial retention size (3).

Cull ring size (mm)	Parameter or variable	2.5 CL	Median	97.5 CL
58.7 (2 5/16-inch)	retention size	4.83	4.91	5.00
	initial retention size	4.59	4.67	4.73
60.3 (2 3/8-inch)	retention size	4.97	5.07	5.17
	initial retention size	4.53	4.65	4.73
61.9 (2 7/16-inch)	retention size	5.05	5.13	5.22
	initial retention size	4.70	4.79	4.87

The percent composition of sampled commercial trips cull ring size usage is presented to characterize the size of cull rings used in the fishery and illustrate the degree of impact if cull ring size requirements were to change (Table 4.2.3). For example, if the minimum cull ring size was increased to 2 3/8-inches, approximately 18% of commercial trips from 2011-2016 sampled were at or above this limit and 15% of commercial trips sampled in 2017. The cost and effort to change the cull ring must also be considered; cull rings can be purchased for around $0.25 each.

Table 4.2.3. Percent of sampled (2011-2017) commercial crab pot trips with various cull ring sizes.

	Percent of Sampled Trips by Cull Ring Size	
Cull Ring Size	2011-2016	2017
2 5/16-inch (minimum legal size)	82%	85%
2 3/8-inch	8%	12%
2 7/16-inch	8%	3%
2 1/2-inch	1%	
>2 1/2-inch	1%	

Number of Cull Rings

Research regarding the number of cull rings in crab pots and the associated reduction in retained sublegal crabs by Rudershausen and Turano (2) determined that increasing the number of cull rings did not significantly reduce catch of sublegal males (Table 4.2.1). Two cull rings have been mandatory in hard crab pots in North Carolina since February 1, 1989, except in exempt areas. In January 2017, the number of cull rings required in hard crab pots was increased to three cull rings as part of the revision to Amendment 2, when the traffic light threshold was met to initiate management restrictions. The number of cull rings required to a pot vary among other states (Appendix 3).

The percent composition of sampled commercial trips is shown to characterize the number of cull rings used in the fishery and illustrate the degree of impact on the fishery if the minimum number of cull rings per pot were to change (Table 4.2.4). For example, if the number of required cull rings was increased to four, approximately 9% of commercial trips sampled were at or above this limit. The cost and effort to change the number of cull rings must also be considered. A new cull ring can be purchased for around $0.25 and effort is required to cut an opening in pot mesh and mount the cull ring. In 2017 the minimum number of cull rings was increased from two to three. Yet 5% of commercial trips sampled in 2017 had less than the minimum three cull rings.

Table 4.2.4. Percent of sampled (2011-2017) commercial crab pot trips with varying sizes of cull rings.

	Percent of Sampled Trips	
Number of Cull Rings	2011-2016	2017
2	87%	5%
3	8%	86%
4	3%	7%
5	1%	1%
>5	1%	1%

Placement of Cull Rings

Research has been done regarding the placement of cull rings in crab pots related to reductions in sublegal crabs. Havens et al. (4) tested pots with modified cull ring placement (Figure 4.2.1). Modified pots had cull rings placed in the corner of the pots and flush with the floor of the upper chamber. Approximately 60% of sublegal crabs escaped modified pots within one hour compared to 4% in unmodified pots. The odds of escapement of sublegal crabs in modified pots in a 24-hour period was eighteen times greater than in unmodified pots. Specific crab reductions from modifying the placement of cull rings in crab pots cannot be calculated and the impact on the fishery is unknown.

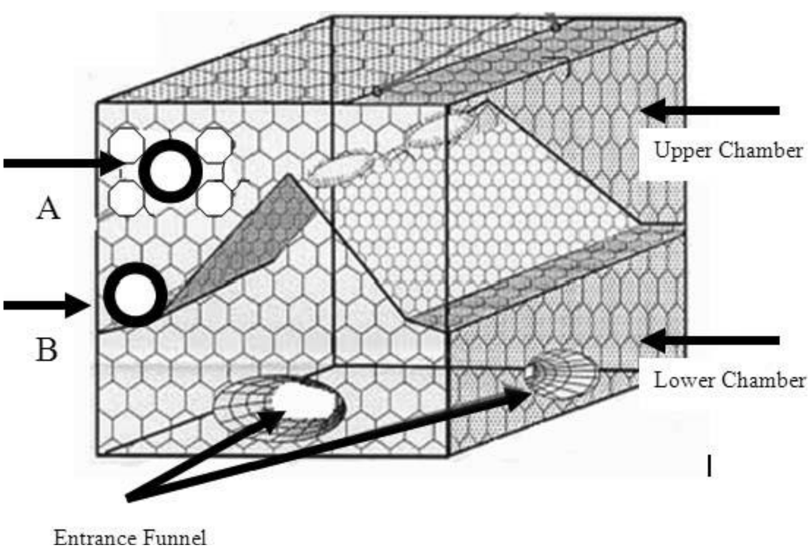

Figure 4.2.1. Placement of cull rings in crab pots: (A) unmodified pots had the cull ring placed on the outer wall of the upper chamber, 15cm above the chamber floor; and (B) modified pots had the cull ring placed in the corner and flush with the upper chamber floor. Source: (4).

In 2016, crabbers indicated adding a third cull ring in the modified position was preferable, as they would not have to close holes created by moving a cull ring. This modified position requirement has been in effect in North Carolina since January 2017. Industry feedback has been positive regarding cull ring placement. Two states besides North Carolina have placement requirements of cull rings (Appendix 3).

Removing Cull Ring Exemptions

Mature female crabs are exempt from the five-inch minimum size limit (NCMFC Rule 15A NCAC 03L .0201 (a)). Some females mature prior to reaching five inches in size and would be unavailable for harvest because once mature they will not grow any larger. Particularly in high salinity areas, such as those with the current escape ring exemption, a portion of the available mature females may be of such a small size they may leave the pot through the 2 5/16-inch escape rings (minimum legal size). Therefore, during the development of Amendment 2, the long-standing proclamation allowing pots to be set without escape rings or with closed escape rings to prevent the loss of small mature female blue crabs in Pamlico Sound and the Newport River were put into rule (Figure 4.2.2). However, the exemption area in Pamlico Sound was reduced by moving the boundary line from six miles from shore to the existing no trawl line behind the Outer Banks.

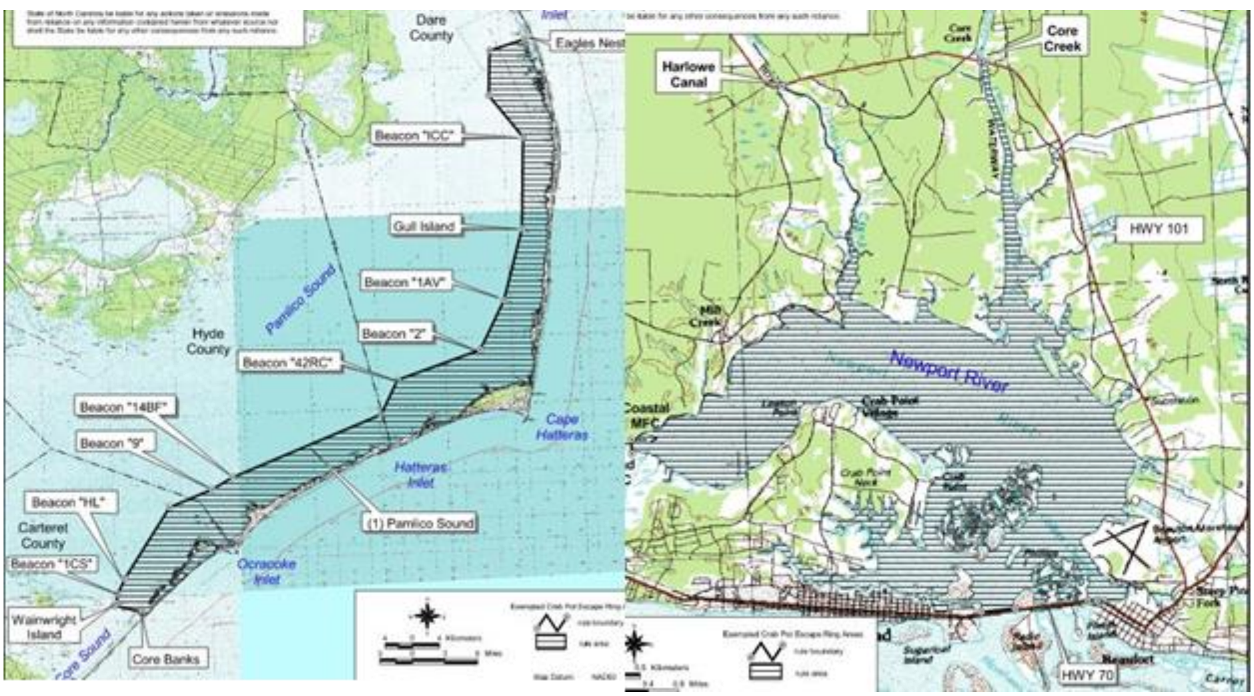

Figure 4.2.2. Escape ring exempted areas in Pamlico Sound, NC (left) and Newport River, NC (right).

Based on NCDMF crab fishery sampling, the escape ring exemption is used in 15% of sampled trips in the allowed areas from 2011-2016 (Table 4.2.5). However, zero trips sampled in 2017 utilized the exemption. Of trips utilizing the exemption, none were from the Newport River. Perhaps in the past when the southern Outer Banks fishery was robust with more crabs and crabbers, the practice of closing the escape rings was more prevalent. Another possibility is there is no market to make it worthwhile for crabbers to retain small mature females.

Table 4.2.5. Percent of sampled (2011-2017) commercial crab pot trips with varying sizes of cull rings in escape ring exempted areas. 2011-2016 n=64, 17 from the Newport River. 2017 n=9, 2 from the Newport River.

	Percent of Sampled Trips	
Number of Cull Rings	2011-2016 (n = 64)	2017 (n = 9)
0	15%	
1	0%	
2	76%	
3	7%	100%
4	2%	

Assuming no cull tolerance for sublegal crabs and a 5-inch minimum size limit, the harvest reduction for eastern Pamlico Sound is approximately 13%. There was not enough commercial crab sampling data specific to the Newport River to estimate harvest reductions for this area. Some measure of recoupment would be likely for both male and immature females. Recoupment for male crabs would likely occur as they grow to the legal minimum size. Recoupment for immature females would likely occur after they undergo their terminal molt and become mature females, which are exempt from the minimum size limit. The recoupment of small mature female crabs would likely be low as some would be able to escape through the existing cull rings.

During development of Amendment 2, NCDMF staff contacted and discussed the Outer Banks escape ring exemption and potential options to modify the boundary with area crabbers. Overall opinions were mixed; but several crabbers indicated they would like to maintain the flexibility to set pots with closed escape rings. If the exemption for these two areas is not removed completely, one alternative would be to reestablish proclamation authority in rule but with specific criteria for the use of that authority. The criteria and resulting rule change could be developed after the adoption of Amendment 3 in conjunction with the Shellfish/Crustacean Advisory Committee. The NCMFC will have the opportunity to weigh in during the rule development process as all rule changes are approved by the commission.

Degradable Panels

An estimated 17% crab pots are lost annually in North Carolina waters (Table 16; 5). Degradable panels disarm gear once lost. This allows organisms which enter derelict pots the ability to leave the trap. Many escape mechanisms rely on hinges or degradable attachments which may fail due to biofouling of the points which hold the panel in place.

During 2002-2005, three different tests were conducted by NCDMF simultaneously in four areas of coastal North Carolina with varying salinities to determine the static degradation of several natural twines and non-coated steel wire (6). Overall, there was a significant amount of variability in the time it took the different materials to degrade within, and between areas and tests. Although, none of the degradable materials had average break times within the critical four-week period when one-third of the annual ghost pot mortality occurred, based on static evaluations, several potentially promising degradable materials were identified for continued testing by commercial crabbers. Additional testing was suggested due to failure rates during deployment and retrieval activities. Table 4.2.6 is an overview of the five test crab pot arrays with varying minimum, maximum, and average break times for each degradable material. Throughout the study, panels functioned better than lid straps. Other states require degradable panels (Appendix 3), which were instituted in part based on the NCDMF 2008 study. This was a complex study with both fishery-independent and fishery-dependent components to the testing, occurring in a variety of environments and salinity regimes.

Table 4.2.6. Minimum, maximum, and average days to break for each degradable material/escapement device, material/device repair time, and percentage of lost catch for functional escapement devices for the commercial crab pot field evaluation in North Carolina, 2005 (6).

		Material – days to break					Percent loss of catch (when device functioned properly)			
Degradable material/escapement device	Total Pots	Number of Pots with Breaks*	Avg.	Min.	Max.	Repair Time (minutes)	Number of Pots with Breaks*	Avg.	Min.	Max.
Lid straps										
Sisal (light)-Lehigh #390/Lid strap	15	11	28	4	58	1.25-10	2	80	80	80
Sisal (heavy) 5/64-inch Cordemex/Lid strap	20	4	76	10	130	1-3	2	67	33	100
Jute (light)-Lehigh #530/Lid Strap	20	11	30	9	72	1-5	5	50	0	100
Jute (heavy) 9/64-inch Winne/Lid strap	15	5	41	25	73	2.25-10	0			
Cotton .062-inch/Lid strap	105	23	37	2	87	1-10	4	79	50	100
Escape panels										
Sisal (light)-Lehigh #390/Panel	30	13	41	5	106	1.25-10	2	100	100	100
Sisal (heavy) 5/64-inch Cordemex/Panel	40	12	50	2	117	1-5	11	97	67	100
Jute (light)-Lehigh #530/Panel	40	21	35	9	165	2-4	15	83	0	100
Jute (heavy) 9/64-inch Winne/Panel	30	14	46	22	107	2.25-10	7	100	100	100
Cotton .062-inch/Panel	35	2	73	72	73	No data	1	100	100	100
Hog Ring 14ga./Panel	35	None								

*Material – days to break, number of pots with breaks is the number of total pots where the material broke. Percent loss of catch, number of pots with breaks is the number of material – days to break, number of pots with breaks where the escape device performed properly (e.g., of 15 pots where light sisal was use, 11 pots had the sisal break and 2 of those 11 pots had the escape device open).

A newer technology has been tested recently in the Chesapeake Bay. Researchers from the Center for Coastal Resources Management, Virginia Institute of Marine Science, College of William & Mary tested polyhydroxyalkanoate (PHA) as a material of choice for biodegradable escape panels. Polyhydroxyalkanoates, unlike plastics or metals, are completely biodegradable by microbes as they are naturally occurring biopolyesters produced by bacteria and used to store energy (7). The PHA break down completely to biomass, water, carbon dioxide, and natural monomers. Panels constructed with PHA have a high certainty of degrading, thus providing an opening the size of the funnel mouth for escapement. To reduce cost, the panel is fabricated to include a cull ring opening as part of the panel (Figure 4.2.3). A blue crab biopanel costs $1.50 each, replacing the $0.25 cull ring. With regular fishing, PHA panel life is extended as UV light inhibits or delays microbe growth, reaching 20 percent loss threshold at about 330 days (8). Although, PHA panels do not degrade within the critical four-week period when one-third of the annual ghost pot mortality occurred, a single panel will degrade 20% within 90 days and reach 40% degraded material (point at which failure is considered) in 180 days (8).

Figure 4.2.3. Polyhydroxyalkanoate biodegradable panel with cull ring and attachment points.

Crab Trawl Tailbag Mesh Size

Existing NCMFC rule requires a minimum stretched mesh of 3-inches for crab trawls for taking hard crabs, except that the Director may, by proclamation, increase the minimum mesh length to no more than 4-inches [15A NCAC 03L .0202 (b)]. Increasing the minimum mesh length of crab trawls in areas not currently under proclamation authority would further reduce catch and mortality of sublegal crab bycatch. In 1992, the NCDMF conducted a study to examine the culling ability of larger tail bag sizes in crab trawls, the number of sublegal blue crabs was reduced by 13% in the 4-inch tail bag and the number of legal crabs was reduced by 7%, as compared to catches in a 3-inch tail bag (Table 4.2.7; 9). Overall survival rates were documented for trawl-caught crabs at 64%, while 93% of the crab pot caught crabs survived (Figure 4.2.4; 10). During a trip in June, a large number of paper shell and soft crabs were killed in the trawling process. Given the high percentage of sublegal blue crabs being captured by the crab trawl fishery, it was recommended that an increase in the minimum tail bag mesh size should be implemented to reduce fishing mortality on this species (9). A reduction of fishing mortality on sublegal crabs should allow more individuals to be available to spawn at a future date. Figure 4.2.5 shows the current boundary for 3-inch and 4-inch crab trawls. Selecting this option would extend the 4-inch minimum mesh size for crab trawls statewide. Increasing the mesh size stateside, based on NCDMF commercial fish house sampling, would impact 84% of fishermen landing crabs from trawl gear.

Table 4.2.7. Total and mean catch weights (kg) of blue crabs for control (3-inch) and experimental (4-inch) tailbags tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992. Table from McKenna and Clark 1993 (*9*).

	Total			Mean		
Common name	3-inch	4-inch	Percent Difference	3-inch	4-inch	|t| value
Total	305.71	268.36	-12.22	9.86	8.66	1.12
Male	74.00	76	2.70	2.39	2.45	0.51
Immature female	45.00	38.55	-14.33	1.45	1.24	0.57
Female	92.00	86.75	-5.71	2.97	2.80	0.27

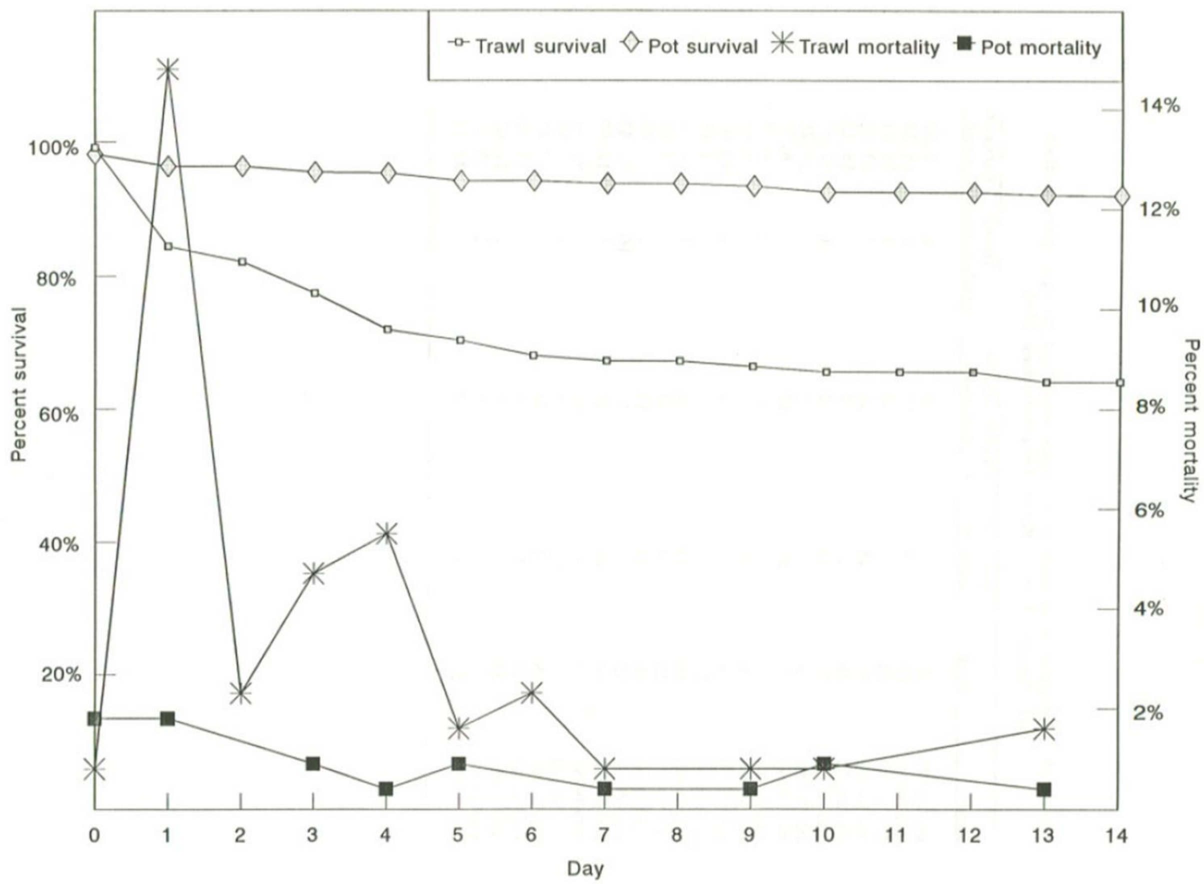

Figure 4.2.4. Cumulative survival rates and daily mortality rates for pot and trawl caught crabs from the Pamlico and Pungo rivers, November 1990-November 1991. High trawl mortality in day 1 is believed to be due to a fish kill in the area a few days before the study began.

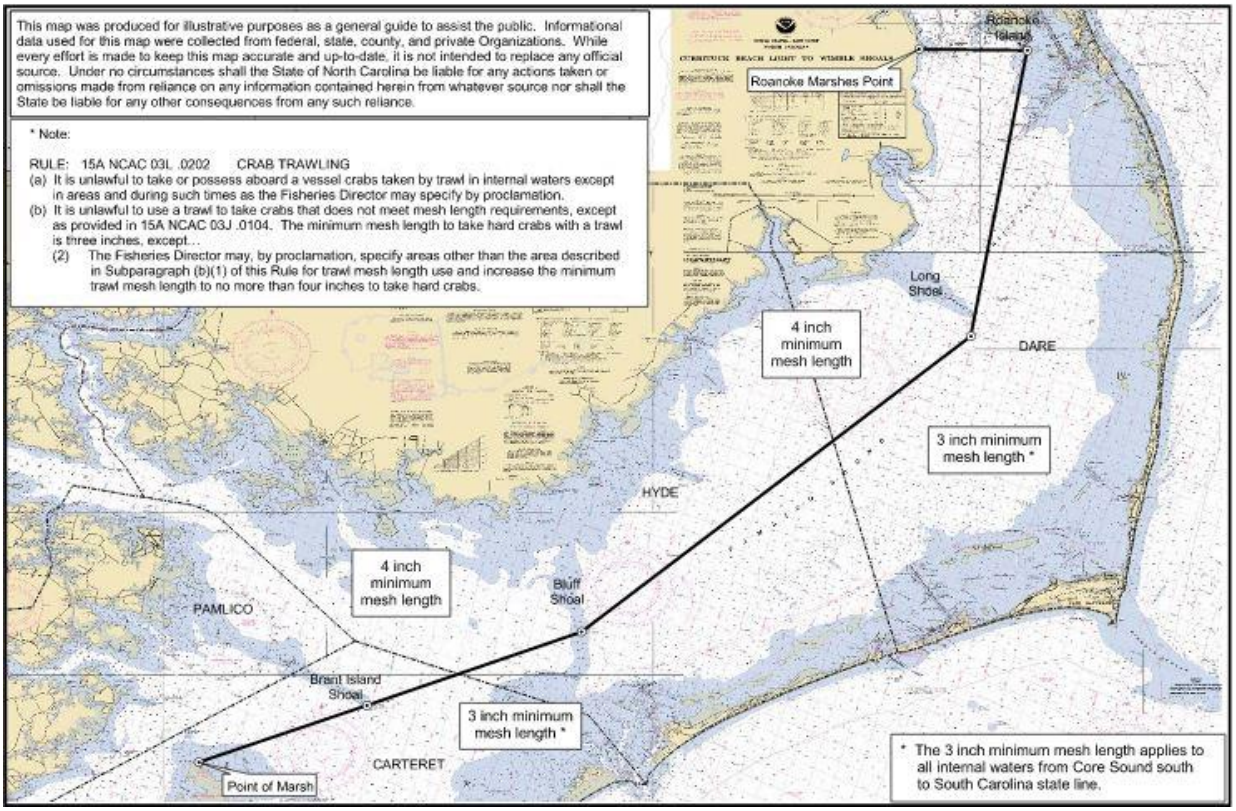

Figure 4.2.5. Current 3-inch and 4-inch crab trawl minimum mesh size boundary in Pamlico Sound.

Limit the Harvest of Sponge Crabs

Sponge crabs are present year-round; however, they begin to appear in significant numbers in March, peaking in May, and persist in lower levels through the summer (Figure 4.2.6). In 2014, the May peak in sponge crabs sampled was greatly evident with 60% of annual sampling occurring in that month. Based on NCDMF fish house sampling, 82% of sponge crabs sampled were from Pamlico Sound 2011-2016 (Table 4.2.8). Often these sponge crab sampling peaks can occur earlier or later in the year than the average May peak. The peak sampling in 2017 was earlier in the season, occurring in March. While in 2011, sampling was evenly distributed wholly between April and July. Prohibition of sponge crab harvest would give mature females the opportunity to spawn and possibly spawn more than once prior to being harvested.

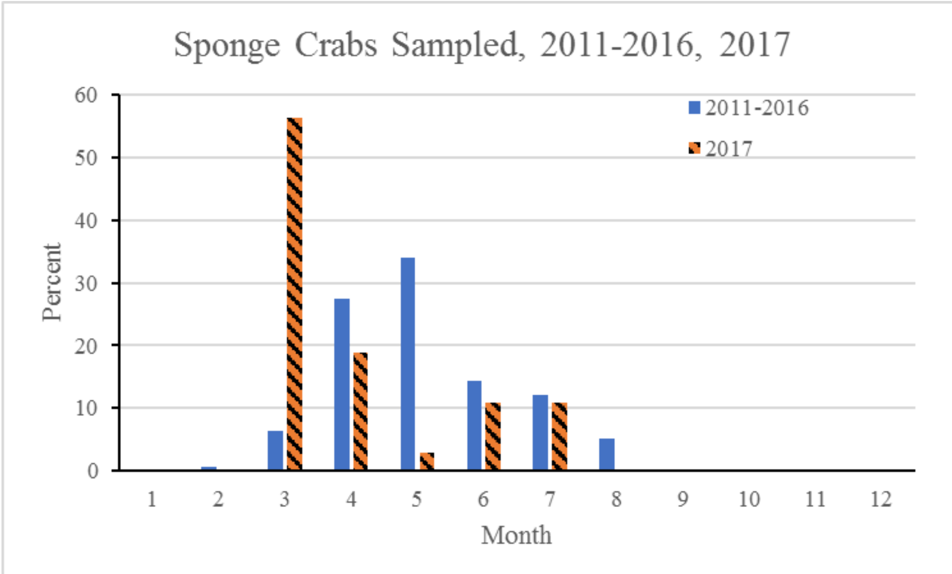

Figure 4.2.6. Average monthly sponge crab frequency in commercial crab sampling, 2011 – 2016, 2017 (2011-2016 n=2,963, 2017 n=571).

A sponge crab closure may be used to restrict harvest during certain times of the year and to reduce removals from the stock and possibly increase recruitment. Since effort can be increased during the open periods of the fishery to offset losses during the closed season, it is best to have seasonal closures that are a minimum of two weeks, but preferably longer. Timing of harvest from the different crab fisheries should also be considered. Since June 6, 2016, dark sponge crabs (brown and black) were prohibited from harvest April 1-April 30. This prohibition has had minimal effect due to the limited duration and specification of sponge color. Additionally, limiting to only dark sponge crabs leads to enforcement complications.

Table 4.2.8. Percent of sampled (2011-2017) sponge crabs by area from NCDMF commercial fish house sampling.

	Year	
Area	2011-2016	2017
Albemarle	< 0.5%	0%
Pamlico	82.0%	62%
Southern	17.5%	38%

Fishing gear interactions may negatively affect blue crab spawning potential. Dickinson et al. (11) reported the majority of sponge crabs caught in pots in the Newport and North rivers of North Carolina had damage to 30-50% of the egg mass. A significantly greater proportion of egg mass damage has been observed of sponge crabs in areas where pots were set as opposed to hand fishing regions of North Carolina (12). Damage may have been from the gear, capture stress, or interactions with other crabs while in pots. Survival of sponge crabs after pot interactions was not affected by sponge damage, however, the likelihood of crabs producing a second clutch was significantly related to previous sponge damage levels (12). Fewer high-damage crabs survived to produce a second clutch (6% reduction). Therefore, an early season closure of the fishery may increase spawning potential of mature females by reducing stress on mature females and reducing damage to egg masses. Removing pots from the water would not only ensure spawning but may also increase future spawning potential of mature females likely to produce multiple clutches.

Size Limit for Peeler and Soft Crabs

Increased effort and harvest in the peeler/soft blue crab fishery and reduced adult harvest has prompted concern about the impacts of peeler/soft crab harvest on the overall health of the fishery. Mature females, peeler, and soft crabs are exempt from the 5-inch minimum size limit for hard crabs [NCMFC Rule 15A NCAC 03L .0201]. Establishing a minimum size limit for peeler and soft crabs would reduce fishing mortality on the smallest crabs allowed for harvest. Short-term effects of establishing a size limit would be reducing the blue crabs available for harvest, which in turn would decrease the overall harvest. Decreasing harvest should have an effect on reducing fishing mortality. In addition, current peeler fishing practice is to employ live male crabs as an attractant or bait to target immature female peelers. Therefore, the majority of peelers harvested are immature females approaching their terminal molt. Reducing fishing mortality on this segment of the population would contribute to efforts to protect the female spawning stock. Establishing a size limit could have a negative impact on the market by reducing the number of blue crabs available for purchase. However, this may be temporary protection as recoupment may occur in the fishery as crabs grow.

Natural mortality of sublegal crabs (less than five inches) is in the range of 26 - 32% per year in the Chesapeake Bay (13). Eggleston (14) estimated an annual mortality rate of 50% for sub-adult and adult blue crabs in North Carolina. Several other states have minimum size limit restrictions for peeler and/or soft crab harvest (Appendix 4.3). A Maryland report noted that raising the peeler size limit would potentially provide an increase in spawning stock biomass by allowing more females to enter the spawning population (15). Raising the size limit should also increase yield to the fishery. Peeler size limits could possibly improve recruit abundance by allowing some immature female crabs to mature and spawn prior to being subject to harvest.

As the time between sheds increases with increasing size, the probability of capture of larger crabs at the peeler stage decreases. The time interval between sheds of 3.0 or 3.5-inch crabs will generally be one to three months (16). The increased yield from a peeler size limit would not be totally lost to natural mortality. The overall value of the peeler/soft crab fishery might be enhanced by a minimum size limit as larger soft crabs generally bring a higher price. A potential adverse impact on the soft crab fishery would be a decrease in market flexibility, particularly during the early spring when product availability is low and small peeler/soft crabs are in demand, bringing very high prices to fishermen. A peeler size limit may increase handling mortality and waste in the fishery. A peeler/soft crab size limit could allow more effective and efficient enforcement of size limits, both in state and out of state as crabs are shipped to states with existing size limits. Therefore, adopting a peeler and soft crab minimum size limit of 3 inches at the point of harvest would address regulatory consistency among the Atlantic Coast states and potentially foster interstate trade.

NCDMF collects size, sex, and maturity (female) information on peeler crabs harvested for commercial shedding operations (Figure 4.2.7). Sample sizes decline considerably when summarized at a waterbody level and thus, only regional and statewide estimates are provided. Assuming no cull tolerance for sublegal peeler crabs, several minimum size limit options were examined in ¼-inch increments of peelers sampled from 2011 to 2017 (Table 4.2.9). For example, if a 3 ¼-inch minimum size limit was imposed on peeler crab harvest, 4.8% of peeler crabs statewide fell into the size classes below this minimum size. The Pamlico region would be the most impacted by the minimum 3 ¼-inch size limit at 7.3% followed by the Albemarle region at 3.2% and the Southern region at 2.1%.

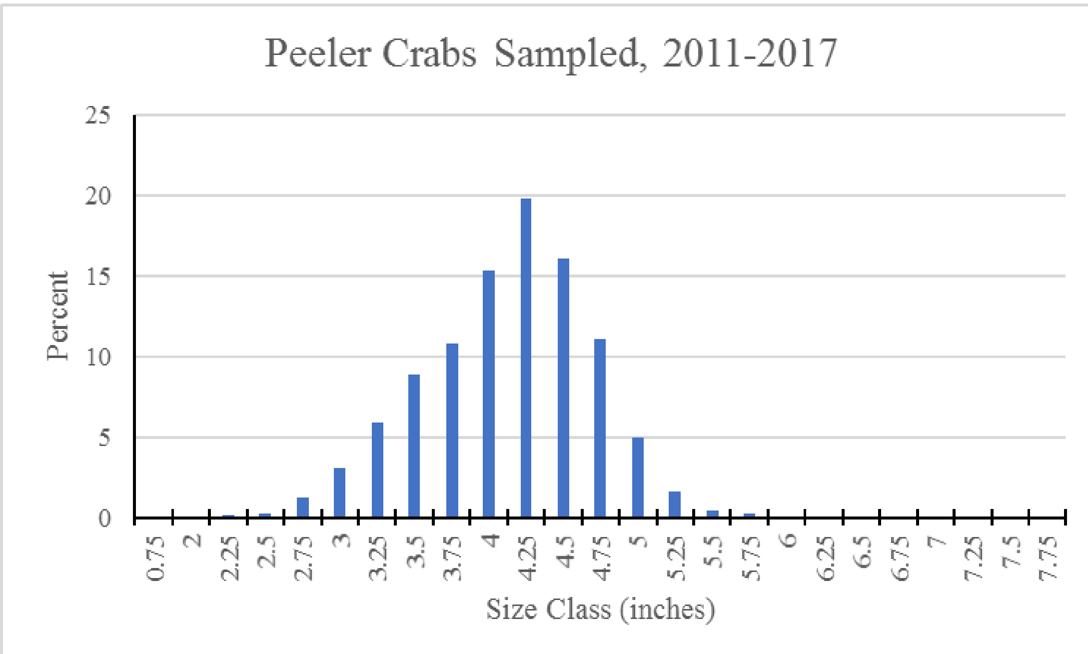

Figure 4.2.7. Average peeler/soft crab size frequency in commercial crab sampling, 2005 – 2017. n=17,708

Table 4.2.9. Estimated harvest reduction percentage (pounds) for various minimum size limits for peeler crabs.

	Peeler Size Limit Reduction Percent			
Minimum Size Limit	Albemarle	Pamlico	Southern	Statewide
3-inch	1.1%	2.8%	0%	1.8%
3 ¼-inch	3.2%	7.3%	2.1%	4.8%
3 ½-inch	6.9%	15.3%	4.1%	10.2%
3 ¾-inch	13.4%	28.2%	10.3%	19.2%

Effort Control

Limiting pots have been discussed since the 1950s. Pot limits are a method of managing effort and improving economic efficiency in the crab pot fishery. The only existing crab pot limit in

North Carolina is a 150 pot per vessel limit in Newport River. This limit was requested by the Newport River crab potters due to gear conflict and has been in existence since 1985.
In 1998 after the Blue Crab FMP was adopted, the NCMFC convened a Regional Stakeholder Advisory Committee to draft an open access plan for the crab pot fishery with discussions including pot limits (17). A considerable amount of time and effort was spent in developing a permit, regional pot limit criteria, and a pot tagging system for enforcement. Consensus could not be reached on an appropriate effort management plan for the blue crab fishery. The NCMFC in 2000 did not implement any aspect of the proposed regional effort management strategy for the crab pot fishery.

The Regional Stakeholder Advisory Committee did not expect effort to increase significantly in the future. While participation has been consistent over time, a marked increase in crab pots occurred in the North Carolina hard crab fishery from 2007 – 2016 (Table 12; Description of the Fishery section). Additionally, the CPUE has remained constant over this time.

Instead of imposing pot limits, restricting to a daily pot fishing time period (e.g., 6 a.m. until 2 p.m.) could potentially reduce the overall amount of gear used and harvest. However, time limits would significantly impact or eliminate fishermen who work other jobs and fish pots after work. Also, problems would develop when full-time fishermen work in tidal areas, generally in the southern region of the state. Such problems as the latter could potentially be addressed through regional management. Many fish houses already restrict fishing times of their crabbers to ensure product is ready for transportation.

Summary of Management Options

Several different management measures are presented in Table 4.2.10. Since projected reductions are not possible for these measures, general effects on landings and economic impacts are presented.

Table 4.2.10. Possible effects to hard crab landings and financial effects on crabbers for each type of management measure.

Management Measure	Effects on Landings	Economic Impact
Increase Cull Ring Size	Neutral	Cost to purchase for all pots Less cull time requires less time on the water and fuel usage
Number of Cull Rings	Neutral	Cost to purchase for all pots Less cull time requires less time on the water and fuel usage
Specify Placement of Cull Rings	Neutral	Cost to add or move cull ring
Remove Cull Ring Exemption	Neutral	Cost to add cull rings
Require Degradable Panel	Neutral	Cost to purchase for all pots Annual cost Replaces need for one cull ring
Increase Tailbag Mesh Size	Minimal reduction in landings	Cost to purchase new tailbag
Limit the Harvest of Sponge Crabs	Reduced landings for limited time Recoupment of catch after eggs shed	Loss of profits
Peeler/Soft Crab Minimum Size Limit	Reduced landings for limited time Recoupment of catch	Loss of profits
Impose Crab Pot Limit	Reduced landings for limited time Recoupment of catch	Loss of profits
Impose Fishing Time Restrictions	Reduced landings for limited time Recoupment of catch	Loss of profits Reduced fuel and gear usage Unfairly impacted crabbers with secondary job

VI. MANAGEMENT OPTIONS

(+ Potential positive impact of action)
(- Potential negative impact of action)

1. Increase cull ring size in pots
    a. Increase cull ring size to 2 3/8 inches
    b. Increase cull ring size to 2 7/16 inches
        + Increase escapement of juvenile crabs
        + May increase juvenile recruitment
        – Decrease harvest with economic loss to the fishery
        – Some regions may be impacted more than others
        – Additional cost to fishermen to make gear modifications

2. Number of cull rings in pots
    a. Increase the number of cull rings in pots to 3 (in effect through 2016 Revision to Amendment 2)
    b. Increase the number of cull rings in pots to 4
    c. Decrease the number of cull rings in pots to 2 (in effect prior to 2016 Revision to Amendment 2)
        + Increase escapement of juvenile crabs
        + May increase juvenile recruitment

- – Decrease harvest with economic loss to the fishery
- – Some regions may be impacted more than others
- – Additional cost to fishermen to make gear modifications

3. Specify placement of individual cull rings in pots
   a. Require one cull ring to be placed within one full mesh of the corner and the apron in the upper chamber of the pot (in effect through 2016 Revision to Amendment 2)
   b. Require two cull rings to be placed within one full mesh of the corner and the apron of the pot located on opposite outside panels of the upper chamber of the pot
      - \+ Increase escapement of juvenile crabs
      - \+ May increase juvenile recruitment
      - – Decrease harvest with economic loss to the fishery
      - – Some regions may be impacted more than others
      - – Additional cost to fishermen to make gear modifications

4. Remove cull ring exemptions to reduce sublegal crabs retained in pots
   a. Remove the cull ring exemption in the Newport River
   b. Remove the cull ring exemption in eastern Pamlico Sound
   c. Remove the cull ring exemptions in the Newport River and eastern Pamlico Sound
   d. Remove the permanent cull ring exemption in rule and replace with proclamation authority to allow the exemption for the Newport River and eastern Pamlico Sound areas (as defined in rule) based on certain criteria. Specific criteria and resultant rule change will be developed in conjunction with the Shellfish/Crustacean AC after the adoption of Amendment 3.
      - \+ Increase escapement of juvenile crabs
      - \+ May increase juvenile recruitment
      - – Decrease harvest with economic loss to the fishery
      - – Some regions may be impacted more than others
      - – Additional cost to fishermen to make gear modifications

5. Require degradable panels in crab pots to disarm derelict gear
      - \+ Increase escapement of juvenile crabs
      - \+ Increase escapement of bycatch species
      - \+ Disarm abandoned or derelict gear
      - \+ Reduce waste from abandoned or derelict gear
      - – Additional cost to fishermen to install and replace panels
      - – Possible loss of legal catch due to premature failure of panels

6. Increase crab trawl tailbag mesh size to 4-inches statewide
      - \+ Increase escapement of juvenile crabs
      - \+ Increase escapement of bycatch species
      - – Some regions may be impacted more than others
      - – Additional cost to fishermen to make gear modifications

7. Limit the harvest of sponge crabs
    a. Prohibit harvest of dark sponge crabs from April 1 through April 30 (in effect through 2016 Revision to Amendment 2)
    b. Prohibit harvest of all sponge crabs from January 1 through May 31
    c. Prohibit harvest of all sponge crabs year-round
        + Increase spawning potential
        + May increase juvenile recruitment
        – Some regions may be impacted more than others
        – Decrease harvest with economic loss to the fishery
        – Increase pressure on other harvest segments (males, immature females, peelers)
        – Increase discards where sponge crabs may still be incidentally caught

8. Peeler and soft crab minimum size limit at the point of harvest
    a. Establish 3-inch minimum size limit for peeler and soft crabs at the point of harvest
    b. Establish a 3 1/4-inch minimum size limit for peeler and soft crabs at the point of harvest
        + May increase spawning potential
        + May increase juvenile recruitment
        – Decrease harvest with economic loss to the fishery
        – Some regions may be impacted more than others
        – Increase discards in the peeler/soft crab fishery
        – May increase discard mortality in the peeler/soft crab fishery

9. Impose a limit on the number of crab pots used
        + Reduce gear in the water
        + May reduce derelict gear
        + Decrease cost to fishermen
        + Possible increase in CPUE with economic benefit to the fishery
        – Increases marine patrol duties
        – Some regions may be impacted more than others
        – Possible decreased harvest with economic loss to the fishery
        – Difficulty implementing a monitoring system
        – Administration would be cumbersome and costly
        – Previous efforts to establish pot limits were unsuccessful

10. Impose a fishing time restriction
        + May decrease the amount of gear fished
        + Aid marine patrol
        – Unfairly impact part-time crabbers
        – Increase number of unattended pots
        – Unfairly impact crabbers in tidal waters

VII. RECOMMENDATIONS

NCMFC Selected Management Strategy

- Option 2a: Maintain number of cull rings in pots to 3, established in 2016 Revision
- Option 3a: Maintain one cull ring placed within one full mesh of the corner and the apron in the upper chamber of the pot, established in 2016 Revision
- Option 4c: Remove cull ring exemptions for Newport River and eastern Pamlico Sound and prohibit designation of exempt areas in future
- Option 7a: Maintain prohibited harvest of dark sponge crabs from April 1 through April 30, established in 2016 Revision

NCMFC Summary

Impact of these measures on recruitment and overfishing cannot always be directly measured from the results of the stock assessment. These qualitative management measures may impact stock assessment metrics, however, the magnitude of these management measures as well as the possible response of the stock is unknown. The NCMFC agreed that such measures from the 2016 Revision to Amendment 2 of the Blue Crab FMP should be retained. Additionally, NCMFC selected option 4c to remove cull ring exempt areas. The rationale behind these selected measures was to provide more escapement protections to mature females to improve their contribution to the blue crab spawning stock. Initial May 1, 2020 implementation of the adopted measures is found in Proclamation M-8-2020.

See Appendix 4.7 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Blue Crab FMP Amendment 3.

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APPENDIX 4.3: ADDRESSING WATER QUALITY CONCERNS IMPACTING THE NORTH CAROLINA BLUE CRAB STOCK

I. ISSUE

Water quality plays an important role in blue crab life history. Improving water quality by addressing pollution sources, especially agricultural runoff, may positively impact the North Carolina blue crab stock.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF).

III. BACKGROUND

Growth and survival of blue crabs is maximized when water quality parameters, such as temperature, salinity, and oxygen, are within optimal ranges. These parameters have been identified by life stage in the biological profile and ecosystem impact on the fishery sections (Ecosystem Impact on the Fishery section). When conditions are outside the suitable range for extended periods or environmental parameters rapidly change, blue crabs can be adversely impacted. North Carolina contains the largest estuarine system of any single Atlantic coast state, with numerous estuarine rivers, creeks, sounds, inlets, and ocean bays creating a diverse system of over 2.3 million acres in size. The Albemarle-Pamlico system is the third largest estuarine complex in North America and the second largest in area in the United States (1). The estuarine water sheds' land area is divided between the Coastal Plain and Piedmont physiographic regions, with the majority of land in the Coastal Plain. Large freshwater influx from rain events or hurricanes and long flushing times of the Albemarle-Pamlico system are related to the major environmental stresses facing benthic communities in these areas (2; 3; 1).

Mortality of blue crabs has been observed from exposure to toxins such as the mosquito abatement chemical piperonyl butoxide (4) and industrial biproduct dioxin (5). Bell et al (6) reported adult blue crab survival declined with increased exposure to hypoxia (low dissolved oxygen). After 30 hours, survival markedly declined with 84.4 percent, 54.8 percent, and 3.1 percent surviving low dissolved oxygen (DO) treatments of 1.5 mg L^{-1}, 1.0 mg L^{-1}, and 0.5 mg L^{-1}, respectively. Additionally, movement and burial diminished, however, crabs in chronically hypoxic waterbodies were able to sustain activity longer than those from other waterbodies. Crabbing productivity is reduced in tributaries with average DO concentration less than 5 mg L^{-1} (7). One cause of hypoxia is blue-green algae blooms. Garcia et al (8) confirmed mycrocystins, toxic blue-green algae which may be harmful to humans, may occur in blue crab tissue samples.

As land use changed $\geq$ 12.8 percent in North Carolina catchments, blue crab catch per trawl declined on average 0.4 crabs per trawl (9). This is opposed to a 0.8 crabs per trawl increase in unaltered catchments. All altered lands can contribute to water quality degradation. Much of the land around the Albemarle-Pamlico Estuarine System, which accounts for the largest amount of blue crab harvest, has been drained to accommodate agriculture and silviculture (Figure 4.3.1).

Agricultural lands include cropland, pastureland, animal operations, and land-based aquaculture. Sowing fields, spraying to protect from pests, preparing crops for harvest, and harvesting activities can all impact water quality in ways that may be harmful to blue crabs. This issue paper will focus on water quality impacts from agriculture and potential management measures. Protecting the waters from impacts of agriculture is promoted through natural resource management with assistance from the North Carolina Department of Agriculture and Consumer Services' Division of Soil & Water Conservation (NCDA&CS S&WC). It is estimated that over two million acres have been drained and developed for agriculture and silviculture along the North Carolina coast. Within each square mile of agricultural land in coastal North Carolina, there are estimated to be more than 20 miles of ditches and canals leading to downstream systems (10; 11).

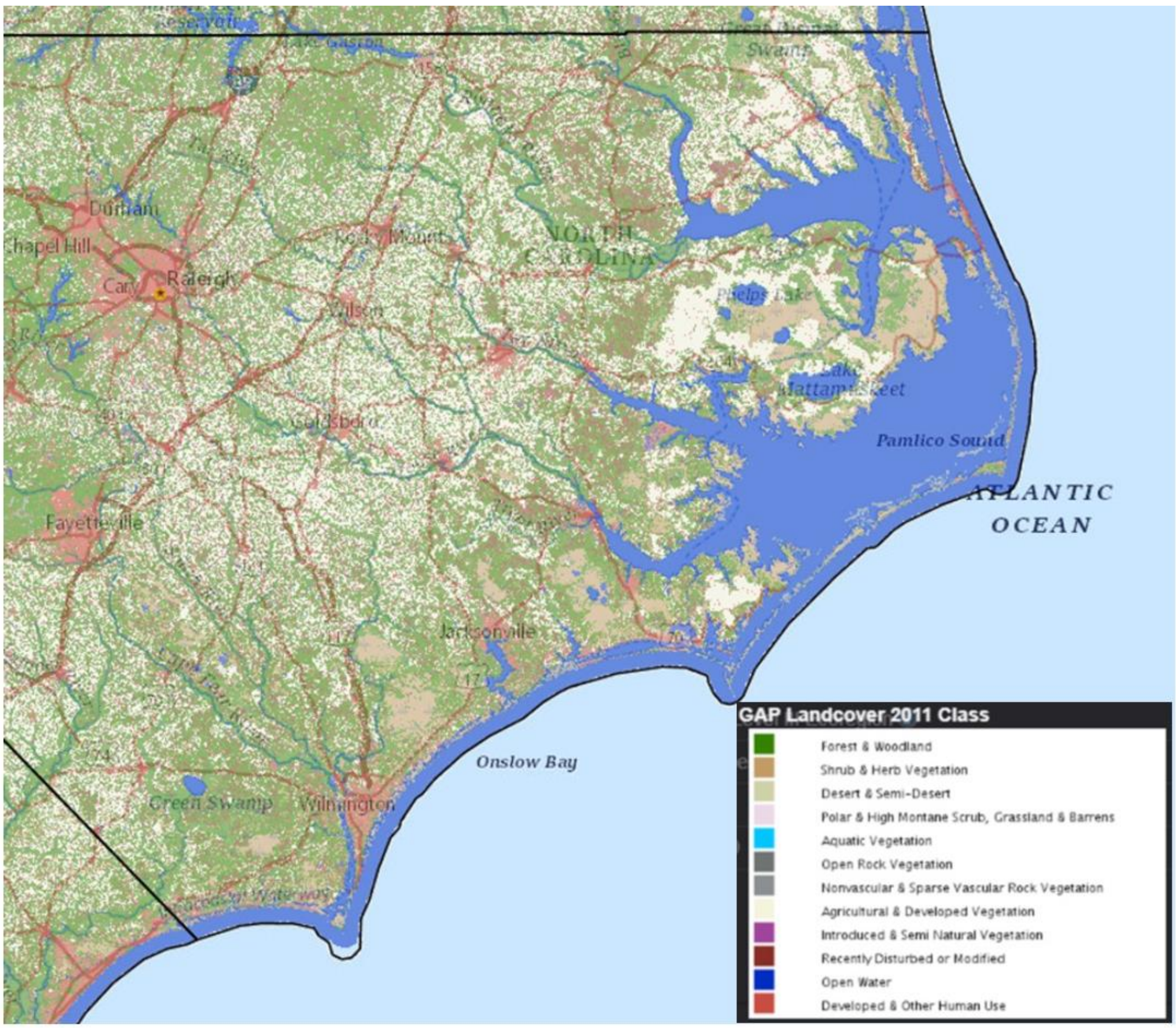


Figure 4.3.1: Land cover types within eastern North Carolina based on United States Geological Survey Gap Analysis Project land cover data.

Negative environmental impacts due to agriculture include pollution from nutrients, eroded soils, and pesticides. Nationally, northern North Carolina coastal watersheds have ranked in the top 10 percent for nitrogen loading from commercial fertilizer applications and rank near the top as measured by potential threats to human drinking water supplies, fish, and aquatic life due to pesticide leaching and runoff (12; 13). Agricultural land in the Neuse River Basin contributed 55 percent of the total annual nonpoint source nitrogen loading post rain event (14). Toxic chemical contamination is not evaluated by North Carolina Division of Water Resources (NCDWR) in estuarine and nearshore ocean waters. Current standards do not eliminate the risk from toxins since: (1) safe levels are not established for many toxic chemicals; (2) mixtures and breakdown products are not considered; (3) effects of seasonal exposure to high concentrations have not been evaluated; and (4) some potential effects, such as endocrine disruption and unique responses of sensitive species, have not yet been assessed.

Nutrient rich environments, poor flushing, abundant fish communities, and brackish salinities are known to promote toxic algal growth (15;16). Outbreaks of the toxic dinoflagellate Pfiesteria occurred in the 1990s in the Neuse, Pamlico, and New River estuaries, which are characterized as shallow, poorly flushed systems (17; 18; 15; 19). Nuisance algal blooms began to occur more often post 1970 and continue to occur regularly in the lower reaches of the Chowan and Neuse rivers (20; 21; 22; 3). Algal blooms are often associated with periods of low DO.

Hypoxia, low DO, is often due to eutrophication (excessive nutrients). Hypoxic events can influence distribution and abundance of blue crabs. In NOAA's 2013 2nd National Habitat Assessment Workshop, it was stated that habitat compression due to low DO may be associated with a 10-50 percent worldwide decline of pelagic predator diversity (23). In North Carolina in 2018, low DO was the cause of 15 of 21 reported fish kills statewide, resulting in mortality of 117,790 individuals (24). Other reported causes include spills and other/unknown causes.

Negative environmental factors affecting blue crab will likely be exacerbated by climate change. Climate change is likely to impact our coastal systems through episodes of extreme weather events which may increase runoff, flooding, and irrigation needs. These impacts can reduce water quality and damage infrastructure in place to transport water on and off the land (25). Warmer temperatures, wetter climates, and increased CO_2 will allow many weeds and pests to thrive, increasing the need for herbicides and pesticides over crops. Bottom temperatures above 25°C are directly correlated to declines on average of 0.6 crabs per trawl catch of blue crabs (9). Heavy episodic rains can increase runoff into receiving surface waters introducing sediment, nutrients, pollutants, animal waste, and other materials making water unusable and in need of water treatment. Conversely, rising sea level and drought can cause coastal waters to become more saline. Higher salinity and water temperature can facilitate the spread of disease through the blue crab stock and alter the life cycle.

On August 14, 1997, Governor James B. Hunt, Jr., signed the Fisheries Reform Act (FRA) into law. The legislation's foremost goal was to ensure healthy fish stocks, the recovery of depleted stocks, and the wise use of fisheries resources. The FRA (G.S. 143B-279.8) requires preparation of Fishery Management Plans (FMPs) by the NCDMF and Coastal Habitat Protection Plans (CHPPs) by Department of Environmental Quality (NCDEQ). The legislative goal of the CHPP is "…the long-term enhancement of coastal fisheries associated with coastal habitats." The law specifies the CHPP identify threats and recommend management actions to protect and restore habitats (and water quality) critical to North Carolina's coastal fishery resources. The plans must be adopted by the Coastal Resources (NCCRC), the Environmental Management (NCEMC), and the Marine Fisheries (NCMFC) commissions, to ensure consistency among commissions, as well as their supporting NCDEQ agencies (26).

While the NCMFC manages fishing practices in coastal waters through rules implemented by the NCDMF, several agencies manage activities affecting coastal fisheries and fish habitats. The EMC has authority over activities affecting water quality, such as point and nonpoint discharges (i.e., agricultural runoff, wastewater, and stormwater) and alteration of wetlands. The EMC's rules are implemented by different NCDEQ agencies, including the North Carolina Division of Water Resources (NCDWR), the North Carolina Division of Air Quality (NCDAQ), and the North Carolina Division of Energy, Mineral, and Land Resources (NCDEMLR). The NCDEMLR administers rules adopted by multiple regulatory commissions, including the NCEMC, North Carolina Sedimentation Control Commission (NCSCC), and the North Carolina Mining and Energy Commission. The NCCRC enacts rules to manage development within and adjacent to public trust and estuarine waters, coastal marshes, and the ocean hazard area. The North Carolina Division of Coastal Management (NCDCM) implements rules adopted by the CRC. The North Carolina Wildlife Resources Commission (NCWRC), while not a principle participant in the CHPP process, has a direct role in the management of fisheries and habitat through the designation of Primary Nursery Areas (PNAs) and Anadromous Fish Spawning Areas (AFSAs) in Inland Waters, the review of development permits, monitoring and management of habitat, and the regulation of fishing in inland waters. There is a myriad of other state, federal, and interstate programs that directly or indirectly influence coastal fisheries habitat in North Carolina.

Surface waters of North Carolina are assessed regularly by NCDWR. These data are used to develop use support ratings biennially and reported to the U.S. EPA. The Integrated Report (IR) to Congress regarding the quality of our nation's waters is a compilation of reports of Sections 303d, 305b, and 314 of the Clean Water Act for the 50 states, 5 inhabited territories, and the District of Columbia. Impaired waters are reported on the 303(d) list. A map of the 2018 impaired waters is available from the NCDWR website as 2018 impaired waters map. DWR monitoring stations within the overall CHPP management unit include approximately 256 ambient stations, 76 fish community sample sites, and 245 benthic macroinvertebrate sample sites. Other water quality monitoring in the CHPP region includes: 22 Albemarle-Pamlico National Estuary Program (APNEP) Citizen's Monitoring Stations, United States Geological Survey special study investigations, and NCDMF fish sampling programs.

IV. AUTHORITY

North Carolina General Statutes
113-134 RULES
113-182 REGULATION OF FISHING AND FISHERIES
113-182.1 FISHERY MANAGEMENT PLANS
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES
143B-279.8 COASTAL HABITAT PROTECTION PLANS

V. DISCUSSION

Pollutants can enter surface waters from point sources, such as waste-water treatment plants or industrial discharge, and nonpoint sources, including runoff from agricultural and developed land. Most pollutants in surface waters are the result of nonpoint source activities (27). Most nutrient pollution in the Albemarle and Pamlico systems has been linked to agriculture activities (28; 29; 30). Runoff can introduce sediments, nutrients, bacteria, organic wastes, toxins, and metals into surface waters. Due to the difficulty in controlling, measuring, and monitoring nonpoint sources, a combination of practices known as Best Management Practices are required or recommended to limit negative effects to the waterways. Best Management Practices on agricultural lands may include riparian buffers, erosion and sediment control, conservation tillage, nutrient management, and pest management plans.

High nutrient levels and low flushing rates increase a waterbody's susceptibility to hypoxia and subsequent fish kills (26). Several North Carolina estuarine environments are characterized by slow moving, poorly flushed waters with high levels of nutrients, offering ideal conditions for algae, fungi, and bacteria to thrive. Algal blooms produce large amounts of oxygen during photosynthesis and raise the pH by increasing hydroxide levels. When the water column becomes supersaturated with DO and has a high pH, this may mean a bloom is in progress. The DWR records algal blooms by measuring DO and pH, assuming a bloom is in progress when DO > 110 percent saturation or > 9.0 mg/L, and/or pH > 8.0 s.u. There were nine blooms in the Albemarle Sound during 2010-2014, usually comprised of blue-green algae. In that same period, the Neuse River had 32 blooms and Pamlico River had 76 blooms of a mixture of algae. The 33 blooms investigated in Calico Creek were mostly comprised of bottom-dwelling diatoms, while the 88 blooms in the New River were a mixture of algae types. Of the 27 blooms investigated in the Cape Fear River, 19 were the blue-green alga Microcystis. Microcystis is almost always toxic and can remain on shorelines in high concentrations for several months after blooms.

When algae begin to die and decay, DO levels can drop suddenly. Low DO (hypoxia) can cause sublethal stress or mortality in blue crabs. Sublethal stress may alter feeding and growth rates, behavior, and vulnerability to predators (31). Where blue crabs could not escape hypoxic waters, mortality occurred when oxygen levels were below 3.0 mg/L for one to three days; mortality occurred within three hours when DO was less than 0.5 mg/L (32). Hypoxic events have resulted in locally elevated mortality among crabs constrained by capture in pots in the Chowan, Neuse, and Pamlico river systems (33; T. Pratt, personal communications). Crab fishermen have indicated they move pots and alter fishing frequency during low oxygen events to avoid blue crabs dying in pots. Adjustments in fishing activity were based on changing environmental observations and catch rates (34).

NCDEQ has regulatory authority over waste management of swine and cattle feedlots that use dry systems and applications of a wastewater or liquid manure; these permitted facilities are inspected by NCDWR on an annual basis. Hog and cattle concentrated animal feeding operations discharging waste have NPDES permits, but there are no associated water quality monitoring requirements. The NCDWR Animal Feeding Operations Unit is responsible for permitting and compliance activities of the ~1,980 permitted animal facilities located in the lower Cape Fear and Neuse River basins. Rothenberger et al. (30), modeling land use in the Neuse River, found that areas with high concentrations of confined swine feed operations were the greatest contributors of nitrogen and phosphorus to the lower Neuse. In 1995, a swine operation lagoon failure led to a spill of raw, concentrated effluent into a second-order segment of the New River, North Carolina. In 1996, Hurricane Fran led to ruptures, excessive overflows, and floodplain inundations of 22 animal-waste lagoons in North Carolina. Elevated chlorophyll-a levels were evident 2-weeks after the 1995 spill with a 100-fold higher blue-green algae community than 1994 densities (17). Chlorophyll-a averaged 110 µg/L by July 5, 1995; substantially higher than the 1996 state acceptable water quality standard of $\leq$40 µg chla/L. Synechococcus and other blue-green algae densities of 10^6 cells/mL and 10^8 cells/mL, respectively, were observed in July 1994 and July 1995. This included a bloom of Phaeocystis flobosa, a harmful blue-green species, with colony densities >10^6 cells/mL. Increases in algal levels can be a major contributor to low oxygen events.

Along with nutrients, pesticides and herbicides may be present in runoff waters. Toxicity of pesticides to blue crab vary greatly due to many factors including application practices, chemical persistence, dilution level, and developmental stage of the blue crab. Eggs and larvae are generally more sensitive to toxins than adult and juvenile life stages as they have more permeable membranes and less developed detoxifying systems (32; 35; 36). Chemical contaminants in the water and soft bottom can adversely impact blue crabs directly by causing mortality, or indirectly by altering endocrine related growth and reproductive processes. Acute toxicity of a variety of herbicides and pesticides to blue crab were determined by the U.S. EPA. These studies stated the presence of chemicals had a detrimental effect and increased mortality rates on larval and juvenile blue crabs, particularly after molting.

Many insecticides function as endocrine disrupters, affecting larval crab development to adult. Fipronil, introduced in 1996, is a commonly used pesticide to control fire ants, cockroaches, beetles, and termites as well as an active ingredient in pet flea and tick treatments. (37). Successful metamorphosis of larval mud crab, Rhithropanopeus harrisii, was shown to be negatively impacted by this type of insecticide (38).

Effects of the pesticide methoprene, a juvenile hormone analog often used for mosquito and flea control, was analyzed in juvenile and adult blue crabs (39). Treatment of megalopae with methoprene delayed successful molting to the first crab stage. After 10 days, 80 percent of treated larvae died as opposed to 25 percent of total larvae in control tanks.

Carbaryl (commercially sold as Sevin) and malathion, are commonly used in agriculture, poultry production, and mosquito abatement. Schroeder-Spain et al. (40) found all treatments of malathion and carbaryl significantly increase righting time (the time it took a crab to flip after being placed upside down) and eyestalk response in both juvenile and adult blue crabs, with malathion additionally decreasing survival time of adult blue crabs. Significant mortality was observed in adult blue crabs; however, reduced righting time and response rate to stimuli make all stages of crabs more susceptible to predation.

Osterberg et al. (41) conducted research on the toxicity of four commonly used insecticides to blue crab at different life stages (Table 4.3.1). Researchers calculated that pesticide overspray into shallow ditches and creeks approximately 0.2-0.4 m deep or less would have concentrations sufficient to kill more than 50 percent of juvenile blue crabs within the affected waters.

Table 4.3.1. Pesticide properties and blue crab lethal concentration required to kill 50% listed in order of decreasing toxicity. Commercial products and their active ingredients common use in North Carolina. (data from *41*)

Compound	Use	Class	24 h LC_{50} (95% confidence interval) (µg/L)	
			Megalopae	Juveniles
Karate®	cotton, peanut, tobacco, soybean, termite abatement	Pyrethroid	0.5260 (0.351–0.789)	3.565 (1.721–7.385)
λ-Cyhalothrin	Karate® active ingredient	Pyrethroid	0.2233 (0.1833–0.2720)	2.701 (2.215–3.294)
Trimax™	fruits & vegetables, tobacco	Chloro-nicatinyl	312.7 (222.4–439.9)	816.7 (692.9–962.6)
Imidacloprid	Trimax™ active ingredient	Chloro-nicatinyl	10.04 (6.381–15.79)	1112 (841.9–1,468)
Aldicarb[a]	potatoes, cotton, peanuts, soybean	N-methyl carbamate	311.6 (281.6–344.8)	291.1 (227.7–372.3)
Orthene®	fruits & vegetables, golf courses	Organophosphate	61,210 (48,500–77,260)	191,300 (141,100–259,000)
Acephate	Orthene® active ingredient	Organophosphate	50,380 (44,300–57,300)	137,300 (132,800–141,900)
Roundup® Pro[b]	weed and brush control	Phosphonoglycine	6,279 (5,937–6,640)	316,000 (167,000–595,200)

The herbicide S,S,S-tri-n-butyl phosphorotrithioate (DEF) is widely used as a cotton defoliant. Rainfall simulations indicated on average 14.5 percent of applied DEF becomes runoff from conventional tillage (42). Habig et al. (43) studied the acute neurotoxic effects of short term exposure to DEF on adult blue crabs. Nerve enzyme activity was reduced more than 90 percent at both concentrations. Recovery of exposed crabs was slow and incomplete, 10 days after transfer to toxin-free water nerves regained less than 40 percent of their normal function.
The Department of Agriculture and Consumer Services administers the NC Pesticide Law of 1971 and the North Carolina Pesticide Board adopts regulations, including crop spraying practices. Policies on drift from aerial applications affect the potential for toxin contamination in coastal waters and associated chronic and acute effects on fish populations. Rules prohibit aerial application of pesticides under conditions that will potentially result in drift and adverse effects to non-target areas. Deposition of pesticides labeled toxic or harmful to aquatic life is not permitted in or near waterways.

The NCDA&CS Pesticide Division investigated a 2012 mass mortality event of peeler blue crabs reported to the Division of Water Resources and Division of Marine Fisheries. The cause of the kill was found to be the pesticide bifenthrin which is commonly used with cotton and considered highly toxic to invertebrates. Rain following spraying of adjacent cotton fields, carried runoff from the fields to the canal where the peeler raceway intake was located. NCDA&CS rules prohibit aerial application of pesticides under conditions likely to result in drift to non-target areas. However, drift of chemicals into surface waters does occur at times and chemicals applied on land can be carried by stormwater runoff through ditches into surface waters. In the 2012 incident, the pesticide application did not violate label application directions, but there were some Best Management Practices that could have been followed to minimize impacts. After the kill, the NCMFC Shellfish/Crustacean Advisory Committee requested the division look into the mass mortality event. The topic was discussed by the NCMFC Habitat and Water Quality Advisory Committee and NCDA&CS staff spoke about the process and the specific incident. As a result of the meeting, the NCDA&CS staff offered to increase outreach and technical assistance to farmers and additional training to pesticide applicators. Information was included on the NCDMF website and in dealer newsletters regarding what to do if a blue crab kill occurs.

North Carolina has several agricultural non-point source programs throughout the state (Table 4.3.2). The NCDA&CS is the lead agency for voluntary agricultural non-point source pollution control programs. The Nonpoint Source Section of the Division of Soil and Water Conservation (DSWC) along with NC Cooperative Extension Service (NCCES), NC Agricultural Research Service (NCARS), Basin Oversight Committee (BOC), and the USDA Natural Resources Conservation Service (NRCS) is responsible for managing several programs related to nonpoint source pollution particularly from agricultural lands and providing technical assistance to Soil and Water Conservation Districts (SWCD) and Local Advisory Committees (LACs). The NCDWR is the lead agency for regulatory agricultural Nonpoint Source (NPS) Pollution control programs.

Table 4.3.2. Agricultural NPS Programs in NC (45).

Category/Program	Local	State	Federal
Agricultural Cost-Share Program	SWCD	DSWC	
NC Pesticide Law of 1971		NCDA&CS	
NCDA&CS Pesticide Disposal Assistance Program		NCDA&CS	
Federal Insecticide, Fungicide, and Rodenticide Act			EPA
Animal Waste Management Regulations	SWCD	DWR, DSWC, NCCES	NRCS
NC Coop. Ext. Service and Ag Research Service		NCARS, NCCES	
Laboratory Testing Services		NCDA&CS	
Watershed Protections (PL-566)			NRCS
Farm Bills Programs			NRCS
Ag Nutrient Regulations in Neuse and Tar-Pam River Basins and the Jordan and Falls Lake Watersheds	LACs	DWR, DSWC, NCDA&CS, BOCs	
Soil, Plant Tissue, and Animal Waste Testing Program		NCDA&CS	

North Carolina water management strategies are developed based on individual watersheds (Figure 4.3.2). Agricultural contributions to nonpoint source water pollution are addressed primarily through encouragement of voluntary participation. This is supported through financial incentives, technical and educational assistance, research, and regulatory programs. A variety of cost share programs are available through DSWC. The Neuse River Basin is the focus of a large-scale, long-term watershed restoration projects underway in the state. The NCDWR initially established 53 rules, enacted in August 1998, with the goal of reducing the average annual load of nitrogen from point and nonpoint sources by a minimum of 30 percent below the average annual load from 1991 – 1995 and then maintain that level. These rules focused on protection and maintenance of riparian areas, wastewater discharge, urban stormwater management, agricultural nitrogen reduction, nutrient management, nitrogen offset fees, and stormwater. As of June 2017, the 30 percent reduction has not been achieved (45). The fifth edition to the Neuse River basin plan is scheduled to be completed in 2019.

Figure 4.3.2. Watershed River basins of North Carolina

Existing state plans recommend water monitoring activities across the state. The CHPP recommends improving strategies throughout river basins to reduce nonpoint pollution and minimize cumulative losses of fish habitat through voluntary actions, assistance, and incentives. This includes improved methods to reduce pollutants from agriculture, increasing use of reclaimed water, increasing use of riparian buffers, and increased funding for strategic land acquisition and conservation. The NCWRC Action Plan (46) states "Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible." The APNEP Comprehensive Plan (47) recommends the use of Best Management Practices on agricultural and silvicultural land, establishing contaminant management strategies for those waters not meeting water quality standards, and development and implementation of coordinated landscape-scale hydrological restoration strategies as well as wetland restoration strategies. Additionally, APNEP Engagement Strategy (48) prioritizes outreach at partner events throughout the Albemarle-Pamlico region. The above plans all encourage citizen science projects to educate and engage the public. These programs create a sense of ownership and accomplishment among participants and connect citizens to natural resources and water quality conservation.

There are many management alternatives that may contribute to success of state plan recommendations. Riparian buffer zones, vegetated ditches, and tailwater recovery systems are Best Management Practices which can reduce containments in nonpoint source runoff. Grass and forest buffers can be effective sediment traps. In North Carolina, Cooper et al. (49) estimated 84 to 90 percent of sediment from agricultural fields was trapped in adjoining deciduous hardwood riparian areas. Silt and clay were deposited into the forest while sand deposited along the edge of the riparian zone. Vegetated ditches may also serve not only to remove suspended solids from runoff but also reduce nutrient loads by reducing flow velocity and adding retention time to allow for precipitation and breakdown before reaching receiving waters (50; 51). Tailwater recovery systems also have the potential to reduce nutrient loading to receiving waters and minimize fertilizer application through recycling captured nutrients in irrigation water (52; 53). The addition of water control structures can increase residence time allowing for nutrient degradation and precipitation out of the water column.

Water quality standards should be based on the assimilative capacity of, and impact to, systems as a whole. The NCMFC should urge the NCDWR and NCDA&CS to expand regulations and outreach aimed at minimizing agricultural impacts on waterways through Best Management Practices. Amendment 1 to the Blue Crab FMP outlines actions for water quality management strategies and recommends existing and future water quality plans are addressed in a timely manner. Additionally, positions are needed for compliance with NCDEQ stormwater and surface water programs. The NCMFC should partner with other state organizations to strategize and implement water quality improvements across basins and plan for coastal resilience to climate change. Working with these organizations, farmers and other citizens of North Carolina must be engaged to instill ownership in natural resources and doing their part to reduce their pollution footprint and improve water quality. Protections and restoration of water quality are essential to a sustainable blue crab stock.

Juvenile Habitat Addition

At its August 2019 business meeting the NCMFC passed the following motion:

"...that in addition to the recommendations included with the current draft Blue Crab Fishery Management Plan Amendment 3, the Division of Marine Fisheries is encouraged to develop an issue paper with pertinent recommendations and/or research needs related to juvenile blue crab habitat availability, habitat quality, and habitat landscape issues analogous to the issue paper developed on water quality impacts (Appendix 4.3 of the draft Blue Crab Fishery Management Plan Amendment 3)."

The following information was added to this issue paper as well as adding juvenile habitat concerns to the management recommendations to address the motion above:

Post-larval and early juvenile blue crabs (< 12 mm carapace width) use SAV for initial settlement and protection while they forage and grow. In the Albemarle-Pamlico estuarine system, most initial recruitment of juvenile blue crabs occurs in SAV beds around inlets behind the Outer Banks. However, in years with large storm events, blue crabs disperse into lower salinity habitats where they recruit into marsh habitat (54). When SAV is lacking blue crabs are forced to recruit into other habitat structure, such as marsh (54), shell bottom (55; 56), detrital matter and woody debris (57).

Like SAV, post-larvae and juvenile blue crabs use wetlands for foraging, refuge, and migration through the estuary (26). This includes detrital matter and woody debris from adjacent wetland vegetation, particularly in the Albemarle and Pamlico systems. Blue crabs utilize marsh edge and woody debris more than unvegetated bottom and occur more regularly in marshes with longer inundation periods (58; 59). They also use wetlands to a greater extent when SAV and oyster reefs are not present, such as in the lower salinity regions of river-dominated estuaries (60). Blue crabs in these lower salinity areas also have higher growth rates and lower predation than in the more saline waters (60). The NCDMF estuarine trawl survey data show blue crab is one of the dominant juvenile species in marshes and shallow tidal creeks (61, 1).

Wetland loss lowers the habitat's capacity to support blue crabs, to trap and filter upland pollutants, and buffer storm events. Wetland losses associated with development and shoreline hardening reduce nursery habitat and food resources available for blue crab. Looking at the effect of land use change on fish abundance, Meyer (9) found a negative correlation between abundance of juvenile blue crabs and conversion of wetlands/undeveloped forest to agriculture/development (where the development change was greater than or equal to 12%). When assessing the effect of bulkheads and living shorelines on fish and invertebrates, Scyphers et al. (62) found living shorelines supported a greater abundance and diversity of aquatic life, with blue crabs being the most clearly enhanced (300% more abundant). Predation related mortality was significantly less at vegetated shorelines than at bulkheads or riprap (63).

Generally, significant reductions in juvenile blue crab habitat mentioned above as well as continued threats to these habitats have likely had significant negative effects on juvenile blue crab recruitment and survival.

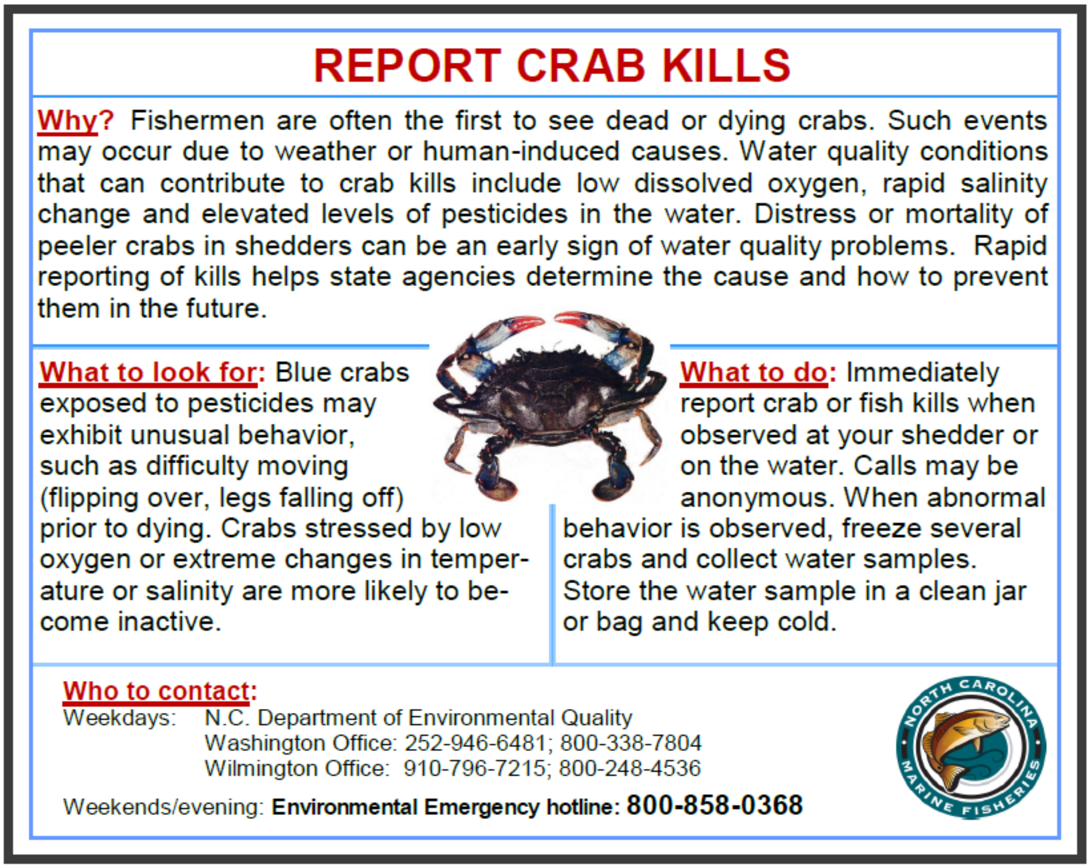
VI. MANAGEMENT OPTIONS

The NCMFC has no regulatory authority over land use and other practices that impact water quality and juvenile habitat. The NCMFC could:

1. Highlight problem areas and advise other regulatory agencies (Coastal Resources Commission, Environmental Management Commission, DEQ Division of Water Quality, Department of Agriculture and Consumer Services, DEQ Division of Energy, Mineral and Land Resources, US Army Corps of Engineers, and local and state governments) on preferred options and potential solutions.
2. Push to create a joint interagency working group to facilitate cooperation and efforts in monitoring and restoring water quality and juvenile habitat. This should include coastal monitoring which is currently limited, including increased United States Geological Survey sampling downstream from wastewater treatment plants.
3. Work with state agencies and interest groups to support maintaining the Clean Water Act at a national level and striving to meet or exceed recommendations
4. Task the CHPP steering committee to prioritize blue crab water quality and juvenile habitat impacts. These should include hypoxia and toxins, while researching specific sources of water quality degradation and their effects on blue crabs.
5. Send letters to the NCDA&CS Division of Forest Resources, Division of Environmental Programs, Division of Soil and Water Conservation, and Department of Transportation to share their concerns about water quality and juvenile habitat and the importance of Best Management Practices, especially buffer zones abutting coastal waters.
6. Invite these agencies to future NCMFC meetings in order to present mitigation efforts on water quality and juvenile habitat impacts, monitoring, and rehabilitation. These may include pesticide and herbicide policies, Best Management Practices reviews, and enforcement.
7. Public outreach is recommended to encourage the public to report crab and fish kills. One possible source of outreach may include a handout when licenses and permits are

purchased and/or renewed (recreational and commercial licenses, and shedding permits) which informs and directs the public how and what to report for these events (Figure 4.3.3).

Figure 4.3.3. Report crab kills post card distributed previously to commercial license holders.



REPORT CRAB KILLS

Why? Fishermen are often the first to see dead or dying crabs. Such events may occur due to weather or human-induced causes. Water quality conditions that can contribute to crab kills include low dissolved oxygen, rapid salinity change and elevated levels of pesticides in the water. Distress or mortality of peeler crabs in shedders can be an early sign of water quality problems. Rapid reporting of kills helps state agencies determine the cause and how to prevent them in the future.

What to look for: Blue crabs exposed to pesticides may exhibit unusual behavior, such as difficulty moving (flipping over, legs falling off) prior to dying. Crabs stressed by low oxygen or extreme changes in temperature or salinity are more likely to become inactive.

What to do: Immediately report crab or fish kills when observed at your shedder or on the water. Calls may be anonymous. When abnormal behavior is observed, freeze several crabs and collect water samples. Store the water sample in a clean jar or bag and keep cold.

Who to contact:
Weekdays: N.C. Department of Environmental Quality
Washington Office: 252-946-6481; 800-338-7804
Wilmington Office: 910-796-7215; 800-248-4536
Weekends/evening: Environmental Emergency hotline: 800-858-0368

NORTH CAROLINA MARINE FISHERIES

VII. RECOMMENDATIONS

NCMFC Selected Management Strategy

- Division habitat staff shall regularly report back to the Habitat and Water Quality and Shellfish/Crustacean ACs with progress on each selected management water quality issue
- Work with other commissions and state agencies to address water quality issues affecting blue crab. Strategies selected are:
    - Highlight problem areas and advise other regulatory agencies on preferred options and potential solutions
    - Create a joint interagency work group for monitoring and restoring water quality
    - Support the Clean Water Act
    - Task the CHPP steering committee to prioritize blue crab water quality impacts [NCMFC identified as the highest priority, Option 4]
    - Send letters to other state agencies regarding concerns and invite them to future NCMFC meetings to present on water quality efforts

- Increase public outreach

NCMFC Summary
The NCMFC recognizes that habitat and water quality are important factors for blue crab sustainability and that the existing collaborative process with other agencies through the CHPP is essential to enact meaningful habitat improvements. Reductions in habitat, especially juvenile blue crab habitat, and declining water quality likely have significant negative effects on blue crab recruitment and survival. The NCMFC tasked division habitat staff to regularly report back to the Habitat and Water Quality and Shellfish/Crustacean ACs with progress on selected management water quality issues.

See Appendix 4.7 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Blue Crab FMP Amendment 3.

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APPENDIX 4.4: EXPAND CRAB SPAWNING SANCTUARIES TO IMPROVE SPAWNING STOCK BIOMASS[1]

I. ISSUE

Consider expansion of existing Crab Spawning Sanctuaries and designation of new Crab Spawning Sanctuaries to protect mature females prior to spawning.

II. ORIGINATION

The 2016 Revision to Amendment 2 to Blue Crab Fishery Management Plan (1) included expansion of existing and/or designation of new Crab Spawning Sanctuaries (CSS) and imposing further fishing restrictions within existing CSS as potential management measures to address low recruitment. Neither the expansion of existing CSS, designation of new CSS, or implementing additional fishing restrictions in the CSS were adopted by the N.C. Marine Fisheries Commission (NCMFC). Expansion of existing and designation of new CSS as well as potential migration corridors are explored in this issue paper.

III. BACKGROUND

Existing Crab Spawning Sanctuaries

In 1965, the law prohibiting the harvest of sponge crabs was repealed and replaced with the designation of five CSS north of Cape Lookout (Table 4.4.1; Figures 4.4.1, 4.4.2, and 4.4.3). The CSS are closed to the use of trawls, pots, and mechanical methods for oysters or clams and to the taking of crabs with any commercial fishing equipment from March 1 through August 31(NCMFC Rule15A NCAC 03L .0205). Existing proclamation authority in NCMFC Rule 03L .0205 allows additional areas to be designated as CSS and allows for further fishing restrictions to be enacted within the CSS. The purpose of these sanctuaries is to protect mature females inhabiting these areas prior to and during the spawning season and to allow them access to ocean waters to release their eggs.

Table 4.4.1. Location and approximate size (in acres) of the five current Crab Spawning Sanctuaries.

Location	Acres
Oregon Inlet	5,788
Hatteras Inlet	4,444
Ocracoke Inlet	8,745
Drum Inlet	5,388
Barden Inlet	4,610

[1] Presented to AC on 4/25/19; Presented to PDT on 3/1/19, 3/26/19, and 5/2/19

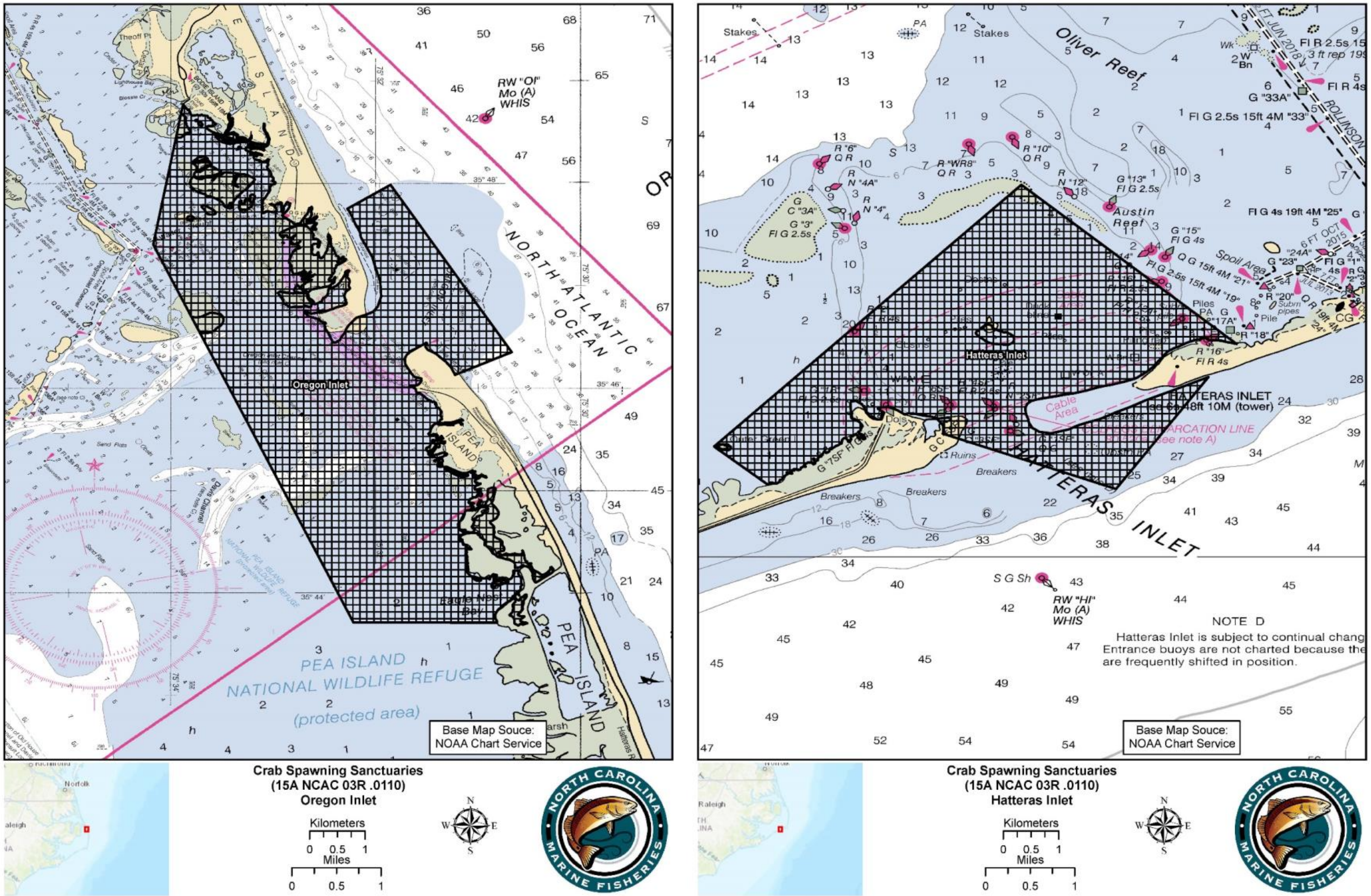

Figure 4.4.1. Current Crab Spawning Sanctuary boundaries for Oregon and Hatteras inlets.

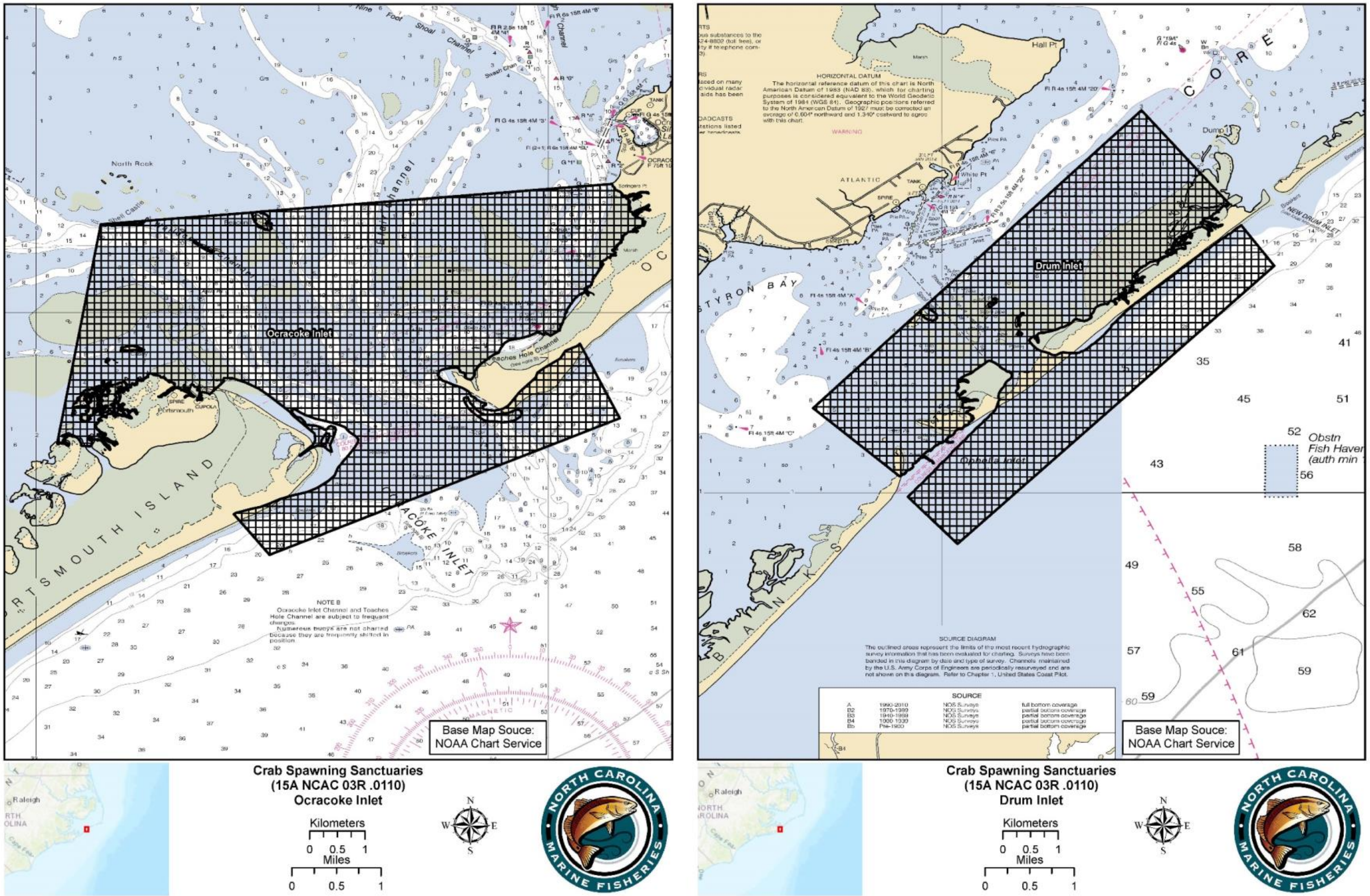

Figure 4.4.2. Current Crab Spawning Sanctuary boundaries for Ocracoke and Drum inlets.

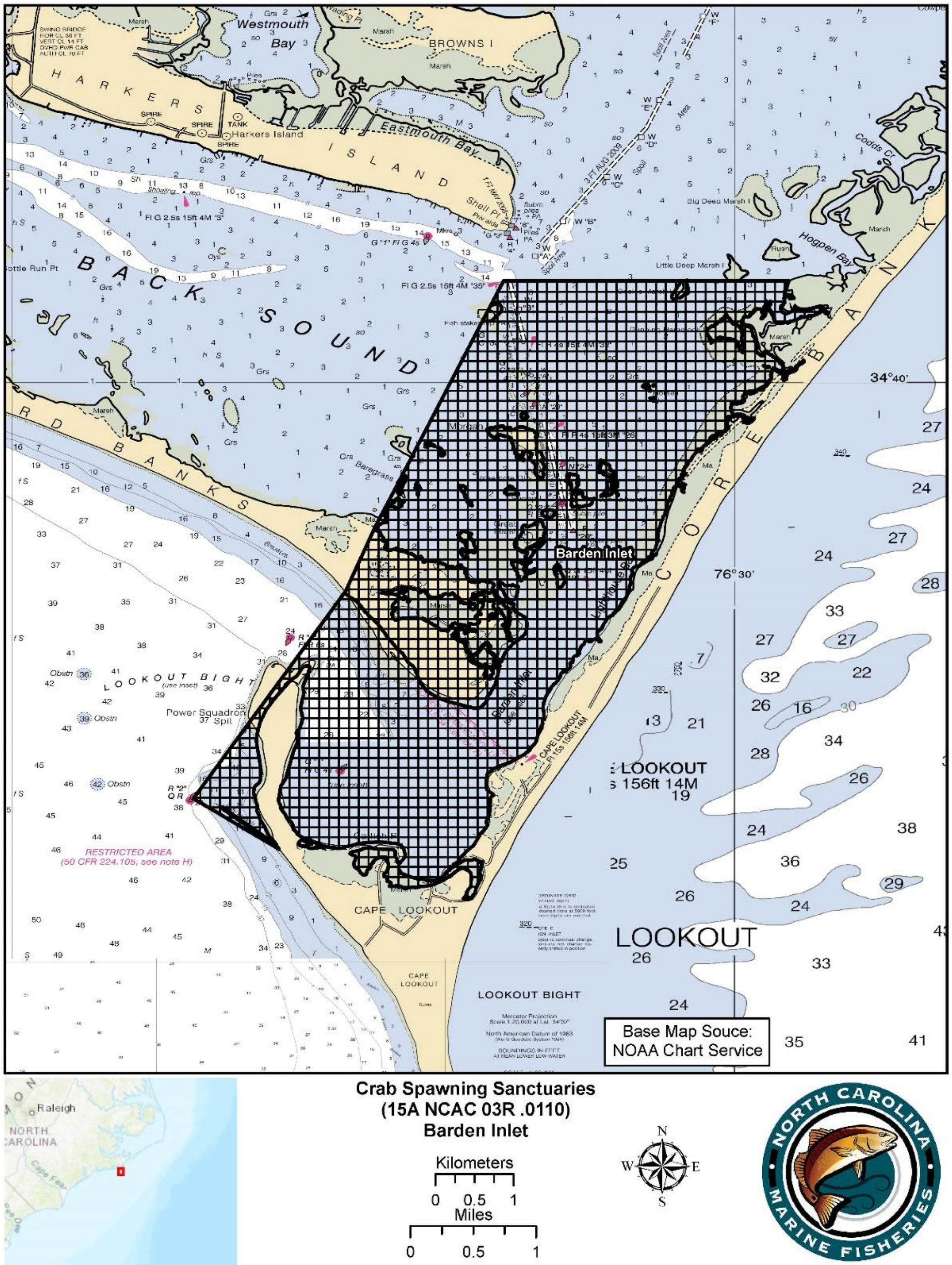

Figure 4.4.3. Current Crab Spawning Sanctuary boundary for Bardens Inlet.

In N.C., blue crab mating peaks in April-June and August-September (2). In the Albemarle-Pamlico system, migration towards the closest inlet starts late September-October for females that mated later in the summer, with spawning the following spring (3). These crabs overwinter in the mud along their migration route or near the inlet system. When mating occurs in early spring, mature female crabs migrate sooner, rather than waiting for fall (2). Commercial crab sampling indicates sponge crabs are most abundant March through May but are typically present from March through August (see Appendix 4.2, Table 4.2.6).

Several studies have looked at the effectiveness of the five existing CSS in North Carolina. Migration distance, tidal regime, harvest effort along the migration route, and the proportion of post-mating mature female blue crabs protected in the sanctuaries influence the ability of mature female blue crabs to successfully reach the protected spawning grounds and thus the overall success of the sanctuaries.

Researchers (4; 5; 6) sampled blue crabs using crab pots in all five sanctuaries during different years. Mature female crabs were present year-round at all the CSS, with abundance greatest from June to August at all sanctuaries except Hatteras, where abundance was greatest in April. Most brown sponge crabs were caught in inlet channels. The abundance of mature females was correlated with salinity (5) and temperature (6). Ballance and Ballance (4) concluded that in wet years mature female crabs are more concentrated and abundant within the sanctuaries than in dry years because they are seeking the higher salinity needed for egg development and spawning. In dry years, the salinity is high in a larger portion of Pamlico Sound west of the inlets so many female crabs are located west of the sanctuary boundaries. The difference in salinity could also explain differences in relative abundance among sanctuaries. Tag return data found that females tagged within the sanctuaries in Pamlico Sound were consistently caught within four kilometers of estuarine sanctuary boundaries (4; 7). Crab dredgers have noted that when temperatures drop early in the fall crabs are more abundant in the designated crab dredge area (J. Midgett, personal communication), suggesting they overwinter before reaching the sanctuary boundaries. The Ballance studies concluded the existing CSS are protecting a portion of egg bearing females, varying with environmental conditions, and that designation of migration corridors or expanded sanctuary boundaries could protect more of the spawning stock.

The effectiveness of the spawning sanctuaries was also assessed by trawling in June, August, and September 2002 inside and up to 2 km outside (sound-side and ocean-side) of the CSS boundaries (8). Results found that relative abundance of mature female blue crabs inside the five sanctuaries combined was not significantly higher than outside the sanctuaries (46.8% inside, 41.9% outside sound-side, 11.3% outside ocean-side). The study estimated that total mature female abundance within sanctuary boundaries only accounted for 0.7% of all mature female blue crabs within the Pamlico and Croatan sounds. Comparing the five CSS, Hatteras and Barden inlets had more mature female blue crabs inside sanctuary boundaries (53.9-64.3%) than outside. In contrast, the opposite was true at the other inlets (37.7-40.0%). The relative abundance of female blue crabs at the inlets (inside and outside of sanctuary boundaries) was highest at the northernmost (Oregon) and southernmost (Drum and Barden) inlets and lowest at Ocracoke and Hatteras inlets. This was attributed to blue crabs migrating to the closest inlet, with Oregon Inlet receiving crabs from Albemarle and northern Pamlico sounds, and Drum and Barden inlets receiving crabs from the Neuse and Tar-Pamlico rivers.

New Crab Spawning Sanctuaries

Crab spawning sanctuaries have not been designated south of Bardens Inlet (14 inlets total). In the southern area of the state, inlets tend to be smaller and occur in closer proximity to each other than in the Pamlico Sound system. Since mature females migrate toward the closest inlet, and there are multiple inlets, mature females are likely to be less concentrated at any one inlet (although the Cape Fear River Inlet may be an exception).

While the density of mature females per inlet may be less than at northern inlets, the closer proximity to the inlets and semi-diurnal tides could facilitate a greater proportion of mature female blue crabs reaching the spawning grounds. The mechanism for migrating long distances varies by tidal regime. In waters with semi-diurnal tides, ovigerous female blue crabs (sponge crabs) have a circa-tidal rhythm, swimming in the water column toward the closest inlet on ebb tides (12.4 hr cycles), or circa-lunar rhythm, swimming once daily during the night ebb tide (24.8 hr cycles) (9). There is rapid seaward movement with ebb tide transport (ETT) following oviposition of the first clutch of eggs (10). Peak swimming speed is around one hour after the tide starts falling. In non-tidal systems, such as most of Pamlico Sound, ovigerous females follow circadian rhythm, swimming seaward at night or walking along the bottom (9). Migration slows once reaching waters where salinity is approximately 22 ppt, the salinity necessary for egg development (2).

A crab tagging and modelling study near Beaufort Inlet, where average tidal currents are relatively strong (1 m/s), found most blue crabs were able to migrate approximately 5 km/day using ETT (11). Crab movement was greater during night ebb tides than day ebb tides or flood tides and increased with current speeds. Ramach et al. (12) found that males and mature females in a high salinity embayment near Beaufort Inlet were partitioned with egg bearing females concentrating closer to the opening of the embayment in slightly deeper water than the males. The female crabs use the embayment to forage until egg release is imminent. In this staging area crabs were able to swim to the inlet within one tidal cycle. Migration speed among individual crabs varied, with some being more active than others (13). Down-estuary walking and swimming in the upper estuary and micro-tidal waters, where currents are slower, helps to successfully move the crabs down to areas with stronger currents. In the Beaufort Inlet system, including North and Newport rivers, Back Sound, and Bogue Sound, all crabs were able to migrate to the inlet within four days (13). The migration patterns noted in the Beaufort Inlet system are thought to be comparable to those in other diurnal systems south of Beaufort Inlet. An acoustic tagging study conducted in the White Oak River found that blue crabs began migrating within days of mating (14). The tagged crabs travelled an average of 0.9 km/day and travelled in the deeper channels (4-5 m water depth), where currents are stronger.

Studies were conducted in the New River in 2006-2007 and in the Cape Fear River in 2005-2006 to assess spatial distribution through the spawning season in these tidal rivers of the southern coast (15; 16). In the Cape Fear River estuary, data indicated that crabs were concentrated in a lower portion of the river from Snow’s Cut to the mouth of the river. Ovigerous females had the greatest abundance in the lower river in July. In the New River, female abundance was highest in July, gradually decreasing through November. The decline was attributed to mature female crabs moving into the shallower creeks and bays. No trend between upper, mid, and lower river sections were detected except the upper zone had significantly less female crabs in September than the lower river. Mature females were found predominantly in the lower river (Stones Bay and south). These findings are consistent with studies from inlets to the north, with mature females being most abundant in the lower system during the summer.

IV. AUTHORITY

North Carolina General Statutes
113-134 RULES
113-182 REGULATONS OF FISHING AND FISHERIES
113-221.1 PROCLAMATIONS; EMERGENCY REVIEW
143B-289.52 MARINE FISHERIES COMMISSIOS – POWERS AND DUTIES

North Carolina Marine Fisheries Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03L .0205 CRAB SPAWNING SANCTUARIES

V. DISCUSSION

Expand Boundaries of Existing Crab Spawning Sanctuaries

A crab spawning sanctuary system is also used in Virginia as a blue crab management tool. The sanctuary boundaries in the Chesapeake Bay were initially found to be ineffective in improving stock size due to the relatively small proportion (16%) of mature female blue crabs that were protected (17). Subsequently, the spawning sanctuary was expanded in 2002 to include a migration corridor, protecting 70% of the mature females. Because post-mating mature females have a lengthy migration and their precise distribution varies seasonally and annually due to weather conditions, the expansion of the historical spawning sanctuary was found to adequately protect mature females (19; 20). This change resulted in a resurgence of the spawning stock (14). Eggleston et al. (8) estimated that <1% of mature female blue crabs in Pamlico and Croatan sounds were protected from harvest (within the spawning sanctuary). Consequently, the protection provided by the CSS in North Carolina is likely insufficient.

Delineating spawning sanctuary boundaries in North Carolina is somewhat more challenging than in the Chesapeake Bay. Unlike North Carolina, the Chesapeake Bay only has one major exit to the ocean so all female crabs inevitably have to concentrate and pass through the migratory corridor and spawning sanctuary. Also, blue crabs were noted to migrate in the deeper channels of the Chesapeake Bay, where depths were 10-14 ft. deep. In contrast, North Carolina has multiple inlets that blue crabs could migrate toward and the bottom is relatively uniform in depth, lacking discrete channels except near inlets.

In addition to the overall small proportion of mature female crabs within the existing CSS, release of eggs prior to reaching the spawning grounds (19) or being caught (14) are other factors that can reduce the effectiveness of the CSS in protecting the spawning stock. Egg release may be more likely to occur in Pamlico Sound where the distance to travel to the inlets is greater, migration is dependent on daily (light) rather than semi-daily cues, and wind-driven currents are slower than tidal flows (10). This supports the need to increase the size of the CSS in Pamlico Sound to better protect the spawning stock.

Ballance and Ballance (4) and Eggleston et al. (8) noted high concentrations of mature females within 4 and 2 km of the CSS boundaries, respectively. Of the five sanctuaries, Oregon, Bardens and Drum inlets had the greatest abundance of mature female blue crabs, likely due to closer proximity to mating grounds. Therefore, inward expansion of the five existing sanctuaries, or the three with the relatively higher abundance, could substantially increase the percent of mature females that would be protected by the sanctuaries.

To help guide any proposed expansion of the existing CSS the blue crab plan and development team reviewed available NCDMF mature female blue crab tagging data (7) and included them on maps showing potential expanded boundary areas. The maps also show the location of oyster cultch planting sites, oyster trigger sampling locations, mechanical clam harvest areas, shellfish leases, and diamondback terrapin interactions where appropriate. Additionally, the current CSS boundaries were examined to ensure they adequately account for movement of the inlets. For example, the existing CSS around Drum Inlet is no longer functional. Ophelia Inlet opened through Core Banks just south of Drum Inlet in 2006 and Drum Inlet closed in 2008-2009. The current boundary for the Drum Inlet CSS does not include all of Ophelia Inlet.

The expanded boundary area of the Oregon Inlet CSS does include some cultch planting and oyster sampling sites but also contains a large number of mature female tag returns (Figure 4.4.4). The expansion areas around Hatteras Inlet (Figure 4.4.4) and Ocracoke Inlet (Figure 4.4.5) contain a few cultch planting sites as well as a significant number of mature female tag returns. The boundary for the Drum Inlet CSS was shifted south to completely cover Ophelia Inlet (Figure 4.4.5). The expansion area around Bardens Inlet covers more deep water area as well as shallow foraging habitat (Figure 4.4.6). Table 4.4.2 shows the acreage of the existing CSS boundaries and the expanded boundaries shown in each map.

Table 4.4.2. Acreage of existing Crab Spawning Sanctuaries and NCDMF recommended boundaries in Amendment 3. * indicates also recommended by Blue Crab AC.

Crab Spawning Sanctuary	Current Acreage	NCDMF Recommended Acreage
Oregon Inlet	5,804	23,332
Hatteras Inlet	4,662	12,282
Ocracoke Inlet	7,914	30,759
Drum/Ophelia Inlet	5,165	5,503*
Barden Inlet	4,637	8,606*

Due to the current regulations in the CSS prohibiting the use of trawls and mechanical methods for harvesting oysters or clams, there could be some impacts to the mechanical oyster, clam and shrimp fisheries if the closure period is extended. For example, expanding the current CSS boundary around Oregon Inlet could potentially impact the mechanical oyster fishery in the area as indicated by the number of cultch planting and sampling sites within the expanded boundary (Figure 4.4.4). The mechanical oyster harvest season occurs from November through the end of March, unless closed earlier due to reaching the management trigger for legal size oysters.

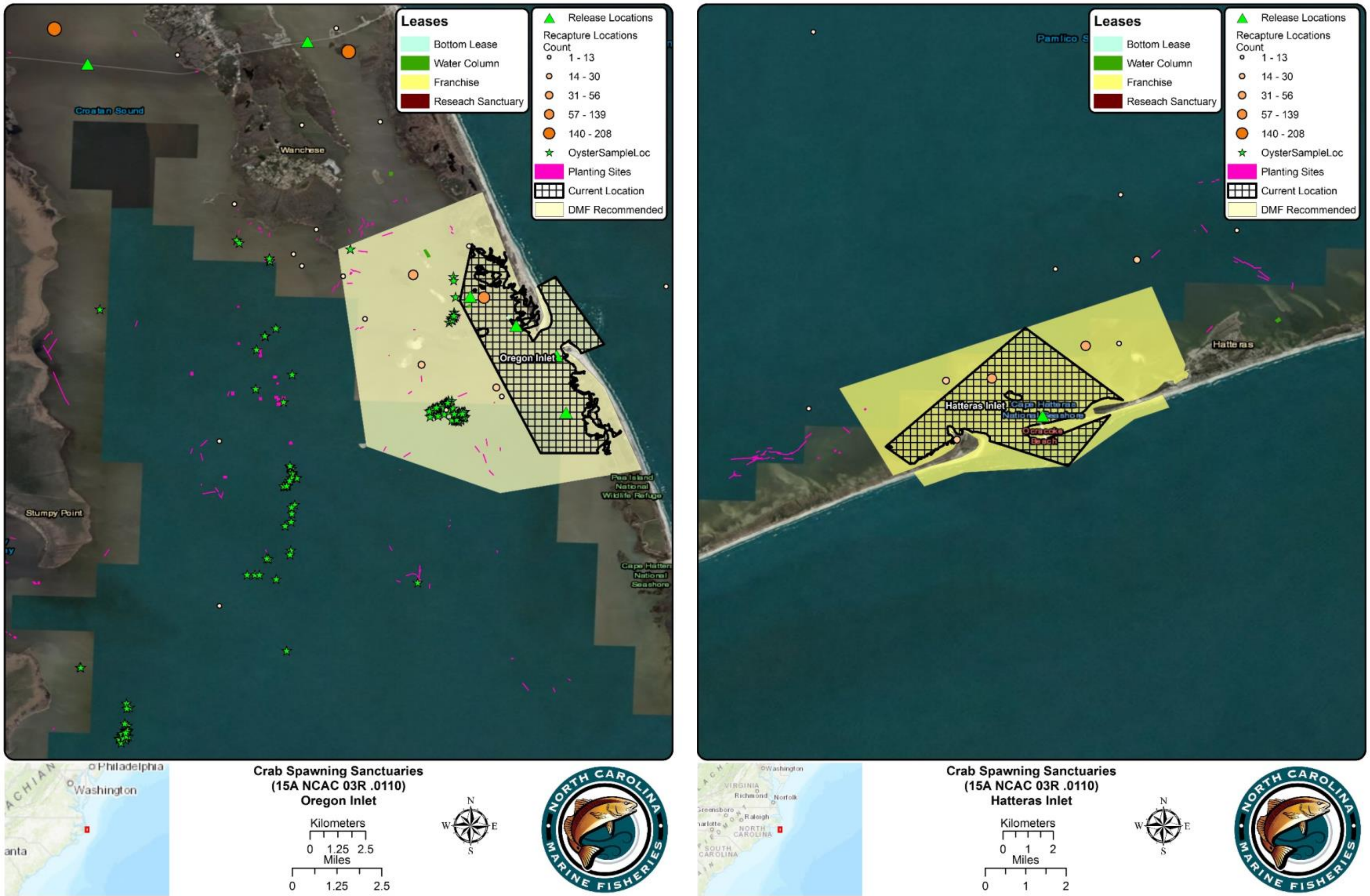

Figure 4.4.4. Proposed locations of new Crab Spawning Sanctuary boundaries for Oregon and Hatteras inlets.

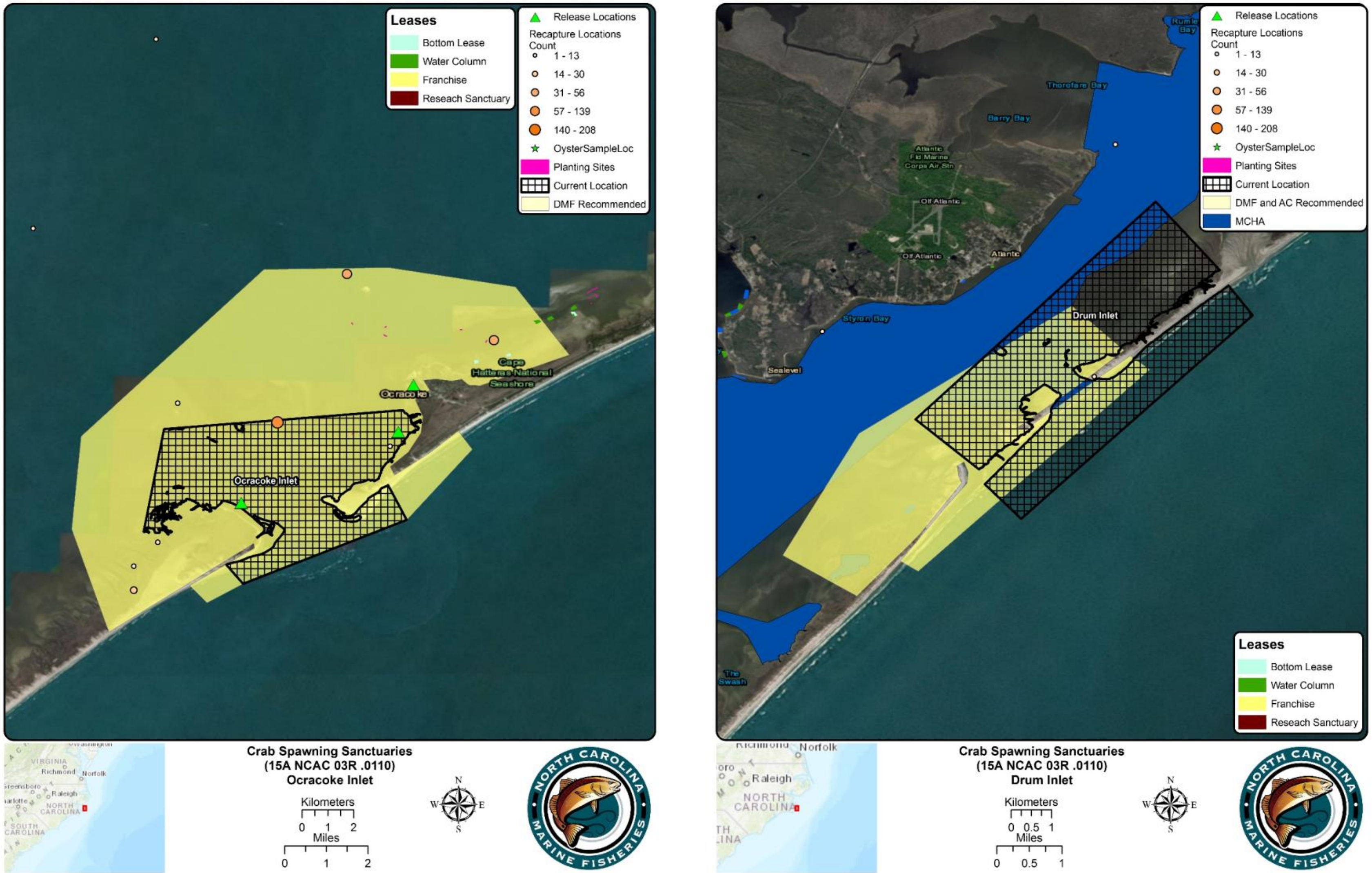

Figure 4.4.5. Proposed locations of new Crab Spawning Sanctuary boundaries for Ocracoke and Drum/Ophelia inlets.

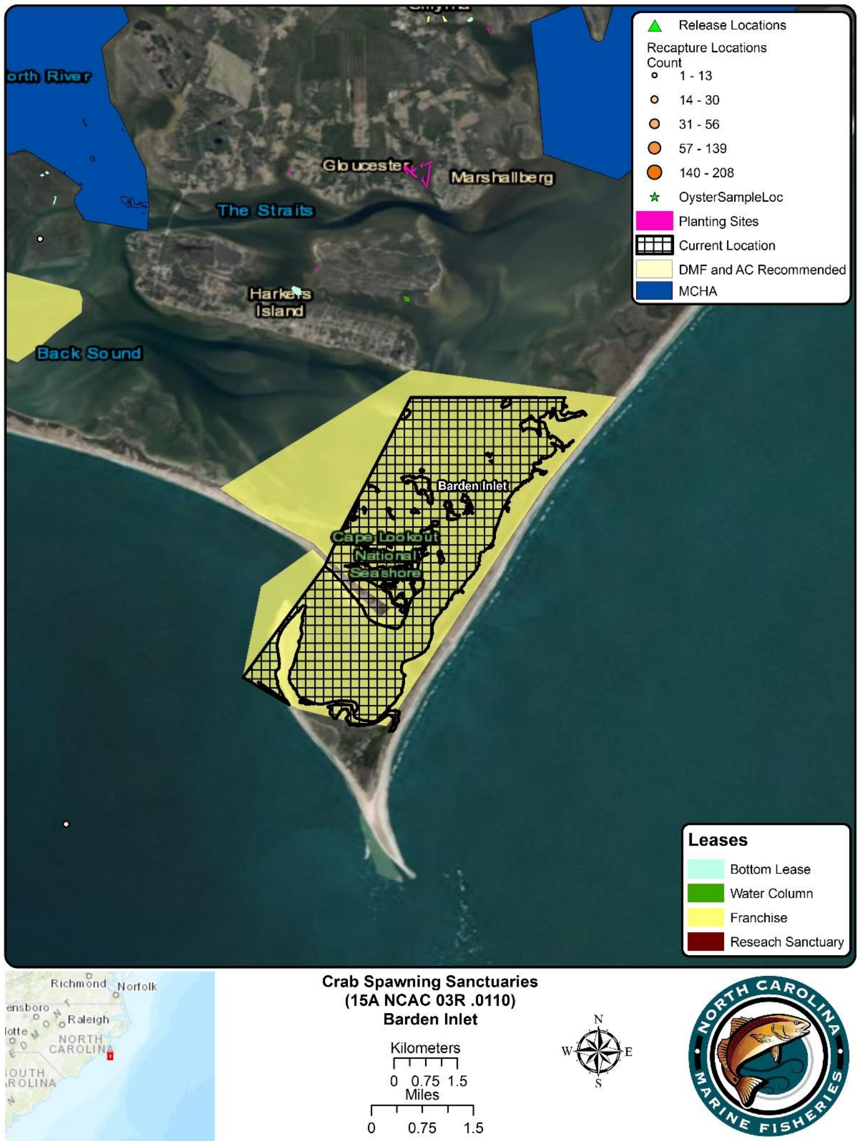

Figure 4.4.6. Proposed location of new Crab Spawning Sanctuary boundary for Bardens Inlet.

Designate New Crab Spawning Sanctuaries

There are 14 inlets that are not designated as crab spawning sanctuaries (Table 4.4.3). These inlets are all south of Barden Inlet. Designating additional crab spawning sanctuaries at some or all of the 14 inlet systems would protect mature females in those areas and enhance local larval recruitment. Average commercial blue crab landings in Core-Bogue sounds and waters south of and including White Oak River account for only 7% of the total average landings from 2007-2016 (Figure 4.4.7). However, crab spawning sanctuaries in these smaller systems could be more effective if a greater percent of mature females are able to reach the protected spawning sanctuaries due to the shorter distance to travel and semi-diurnal tides accelerating migration rates.

Table 4.4.3. Inlets without designated Crab Spawning Sanctuaries south of Barden Inlet, listed north to south.

Inlet Name	
Beaufort	Mason
Bogue	Masonboro
Bear	Carolina Beach
Browns	Cape Fear
New River	Lockwoods Folly
New Topsail	Shallotte
Rich	Tubbs

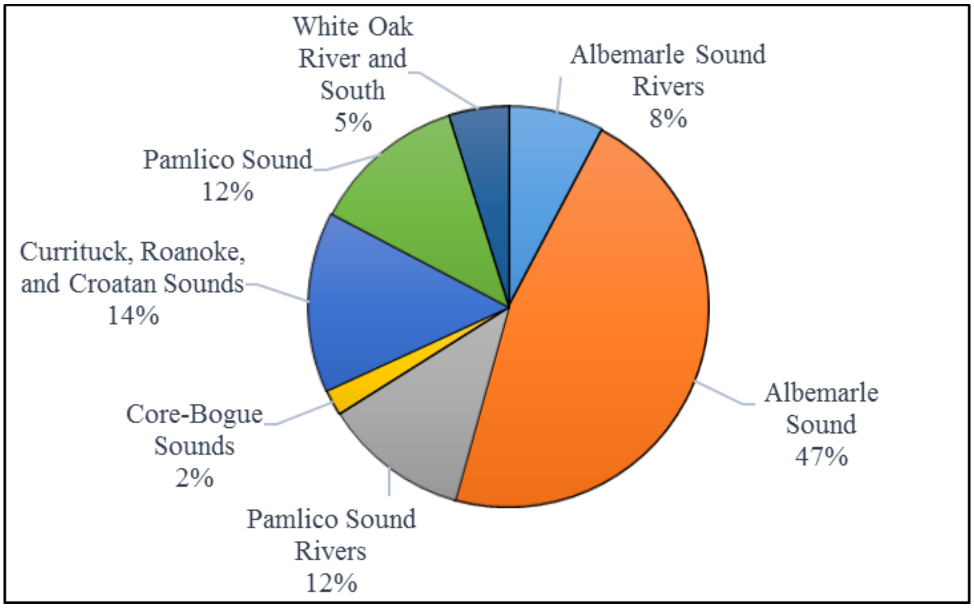

Figure 4.4.7. Percent of commercial crab landings by waterbody, 2007-2016.

Without designated CSS south of Cape Lookout, none of the spawning stock is protected in the southern region of the state. Designating additional CSS would further protect mature females as they migrate to spawning grounds. Designations could be limited to the largest and most stable inlets, or to those that contribute the most in terms of use by spawning females. Of the 14 inlets, the largest are Beaufort, Bogue, and Cape Fear River. Unfortunately, research has not been done to assess abundance of mature female blue crabs at most of the inlets in this region.

Spawning sanctuaries around the southern inlets would prohibit crab pots, trawls, and mechanical methods for harvesting clams and oysters for a portion or all of the year, depending on the management strategy chosen. Creating sanctuaries in the southern inlets could have a short-term impact on blue crab landings but could lead to a long-term increase in the population and future harvest. Local crabbers have suggested the deep fast flowing waters of the lower Cape Fear River ship channel provide a natural barrier to some crab harvesting practices in that area. Thus, this area serves as an unofficial sanctuary for all blue crabs (1).

Inlets are critical corridors that all estuarine dependent migratory species must pass through to complete their life cycle. Ogburn and Habegger (20) suggested the primary spawning habitat of blue crabs may be in coastal ocean waters in the South Atlantic, with inlet systems functioning more as spawning migration corridors. Regardless, mature female blue crabs are concentrated in the vicinity of inlets seasonally and must reach or pass through them to spawn. Other species could also benefit from seasonal restrictions on trawls, including shrimp and associated bycatch species. The extent of trawling effort that occurs within the inlet systems is unknown since the inlet systems are smaller than the commercial trip ticket waterbodies used to track commercial landings. Therefore, the impact of designating CSS in these areas on the shrimp trawl fishery is unquantifiable. Examples of potential sanctuary boundaries are shown in Figures 4.4.8-4.4.14. These figures show the proposed CSS boundaries from the 2016 Revision to Amendment 2 to the N.C. Blue Crab FMP as well as alternative boundaries based on the research discussed above. Table 4.4.4 shows the estimated acreage of the proposed CSS boundaries from the 2016 Revision and the alternative boundaries.

As above, maps for the potential new CSS include NCDMF mature female blue crab tagging data (7) and the location of oyster cultch planting sites, oyster trigger sampling locations, mechanical clam harvest areas, shellfish leases, and diamondback terrapin interactions where appropriate. Sanctuary boundaries in the Atlantic Ocean are approximate and meant to extend roughly 100 yards from shore from the mean high-water mark.

Table 4.4.4. Proposed Crab Spawning Sanctuary acreages by inlet from Beaufort Inlet south. *Where recommendations differ for NCDMF and AC, value in parentheses is for AC recommendation.

Crab Spawning Sanctuary	NCDMF and AC Recommended Acreage
Beaufort Inlet	4,250
Bogue Inlet	1,427
Bear Inlet	439
Browns Inlet	286
New River Inlet	803
Topsail Inlet	930
Rich Inlet	420
Mason Inlet	334
Masonboro Inlet	519
Carolina Beach Inlet	276
Cape Fear River Inlet*	3,846 (3,695)
Lockwoods Folly Inlet	264
Shallotte Inlet	411
Tubbs Inlet	141

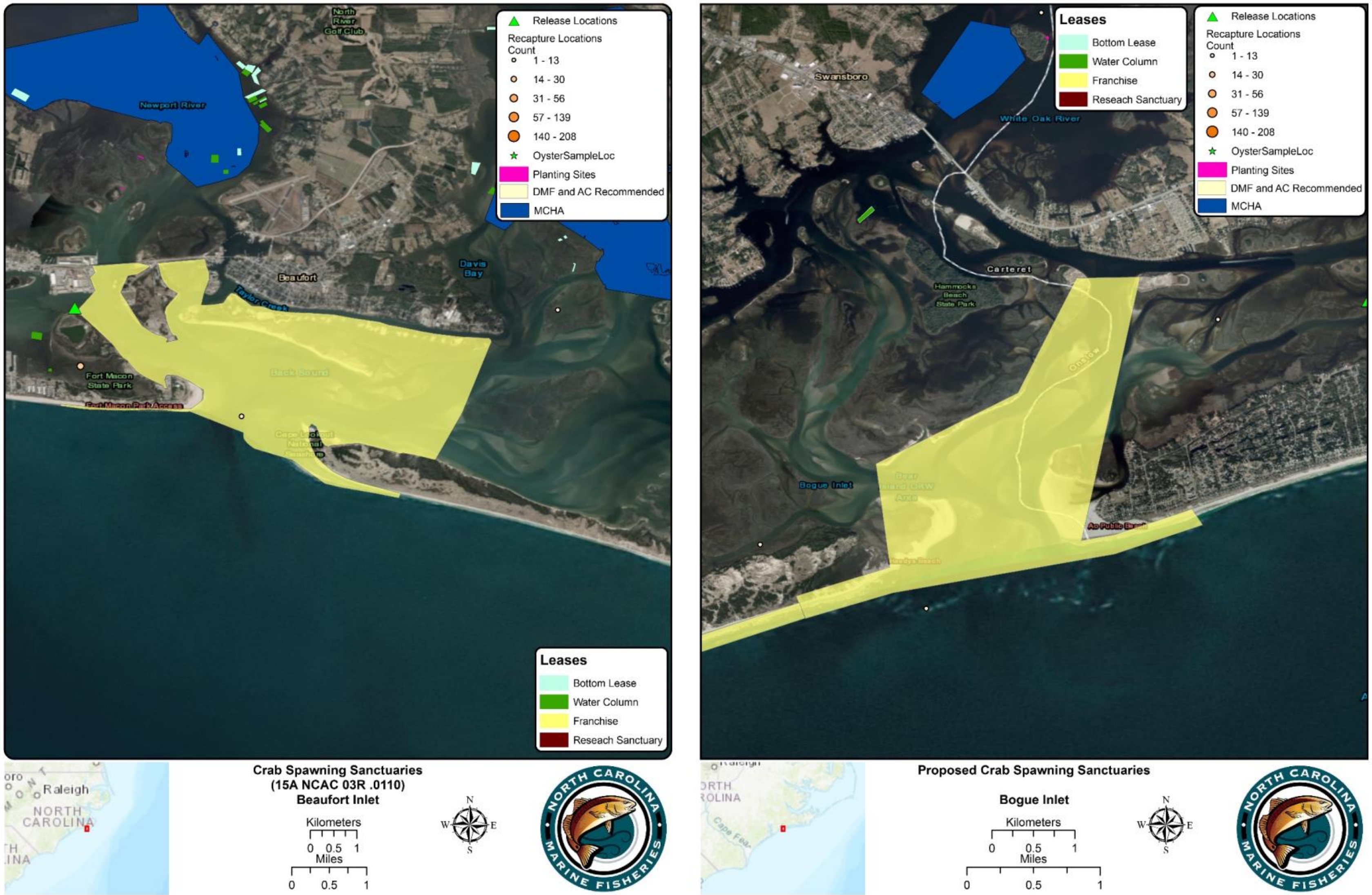

Figure 4.4.8. Proposed locations of new Crab Spawning Sanctuary boundaries for Beaufort and Bogue inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

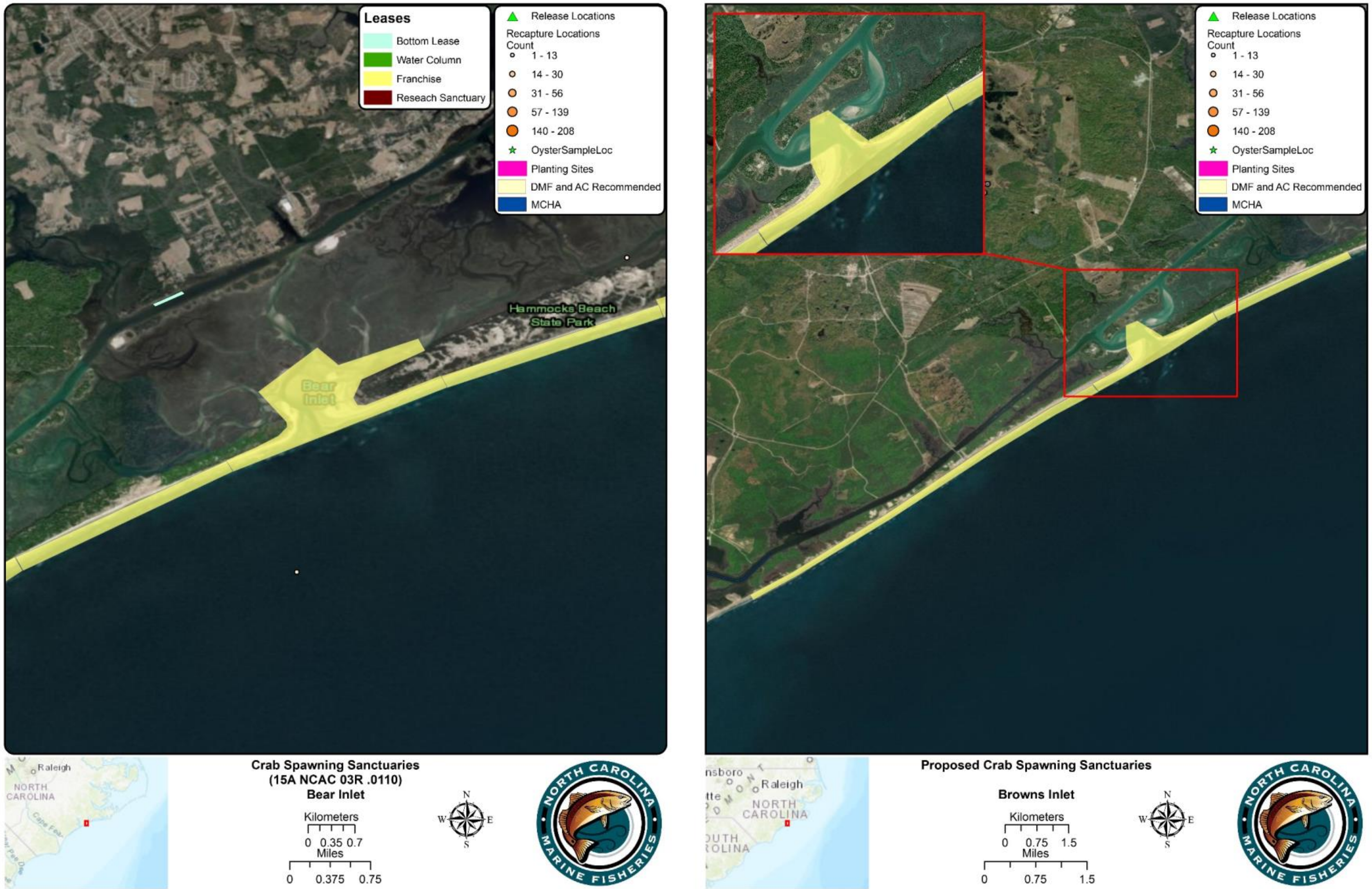

Figure 4.4.9. Proposed locations of new Crab Spawning Sanctuary boundaries for Bear and Browns inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

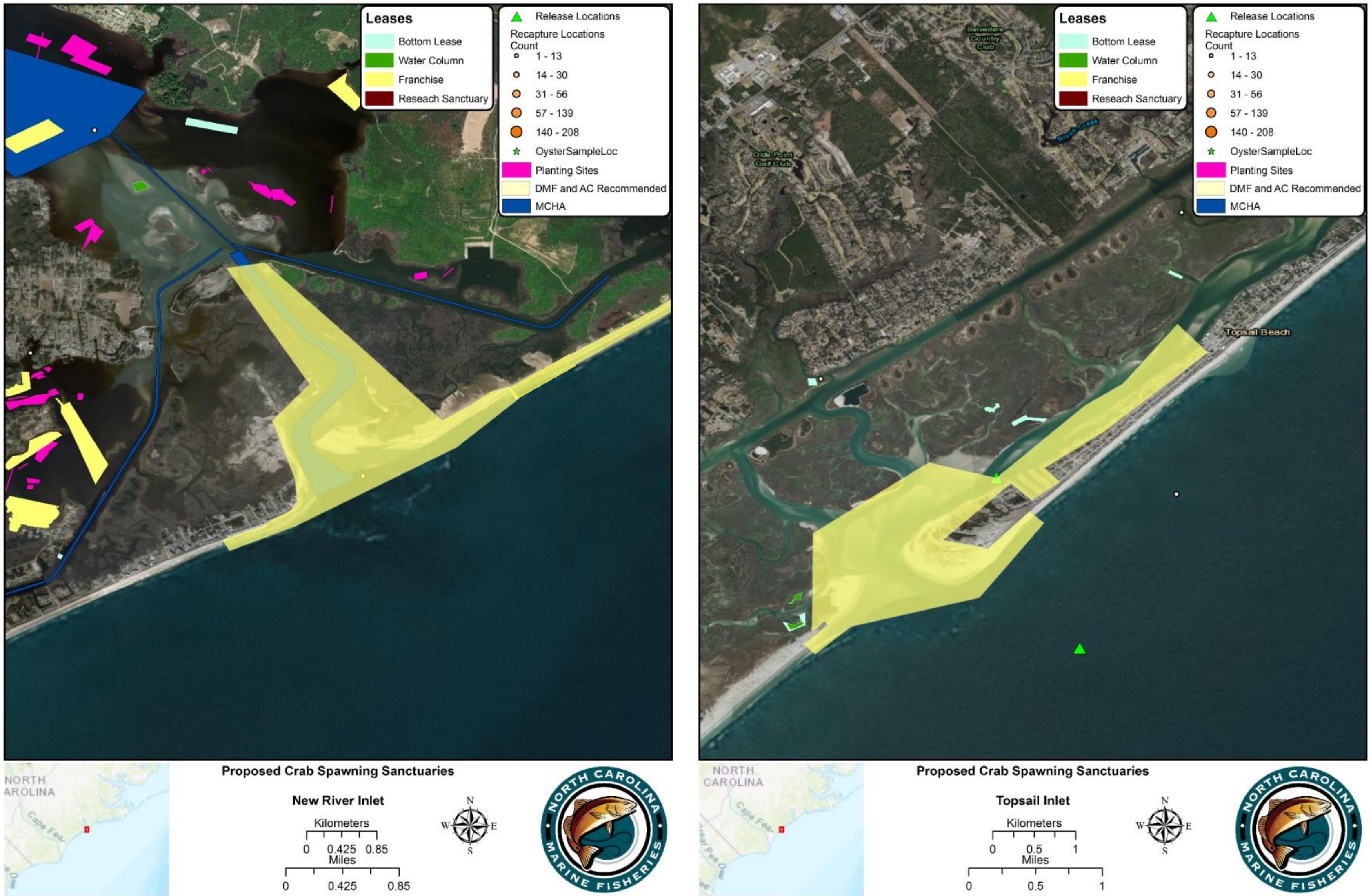

Figure 4.4.10. Proposed locations of new Crab Spawning Sanctuary boundaries for New River and Topsail inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

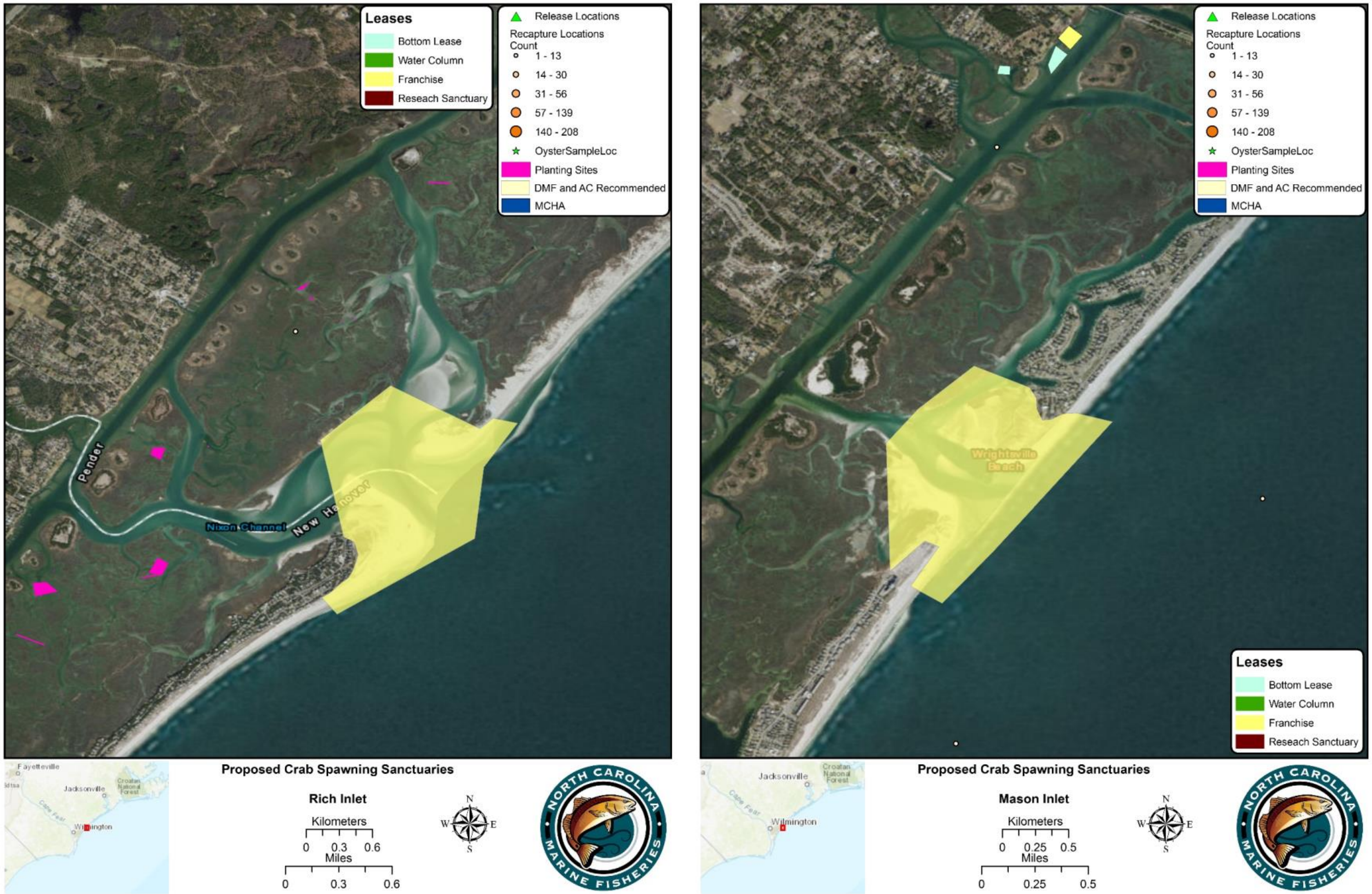

Figure 4.4.11. Proposed locations of new Crab Spawning Sanctuary boundaries for Rich and Mason inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

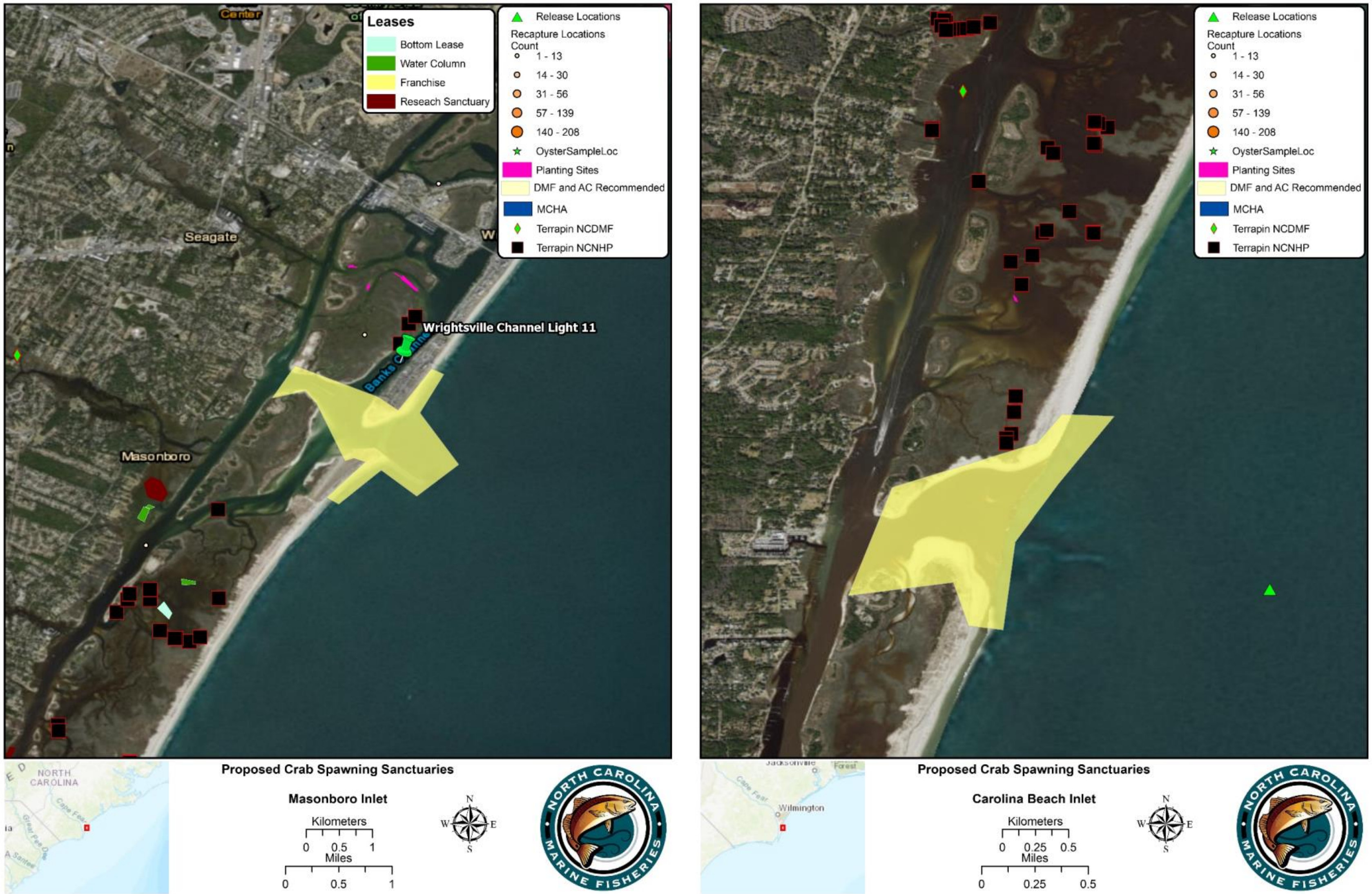

Figure 4.4.12. Proposed locations of new Crab Spawning Sanctuary boundaries for Masonboro and Carolina Beach inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

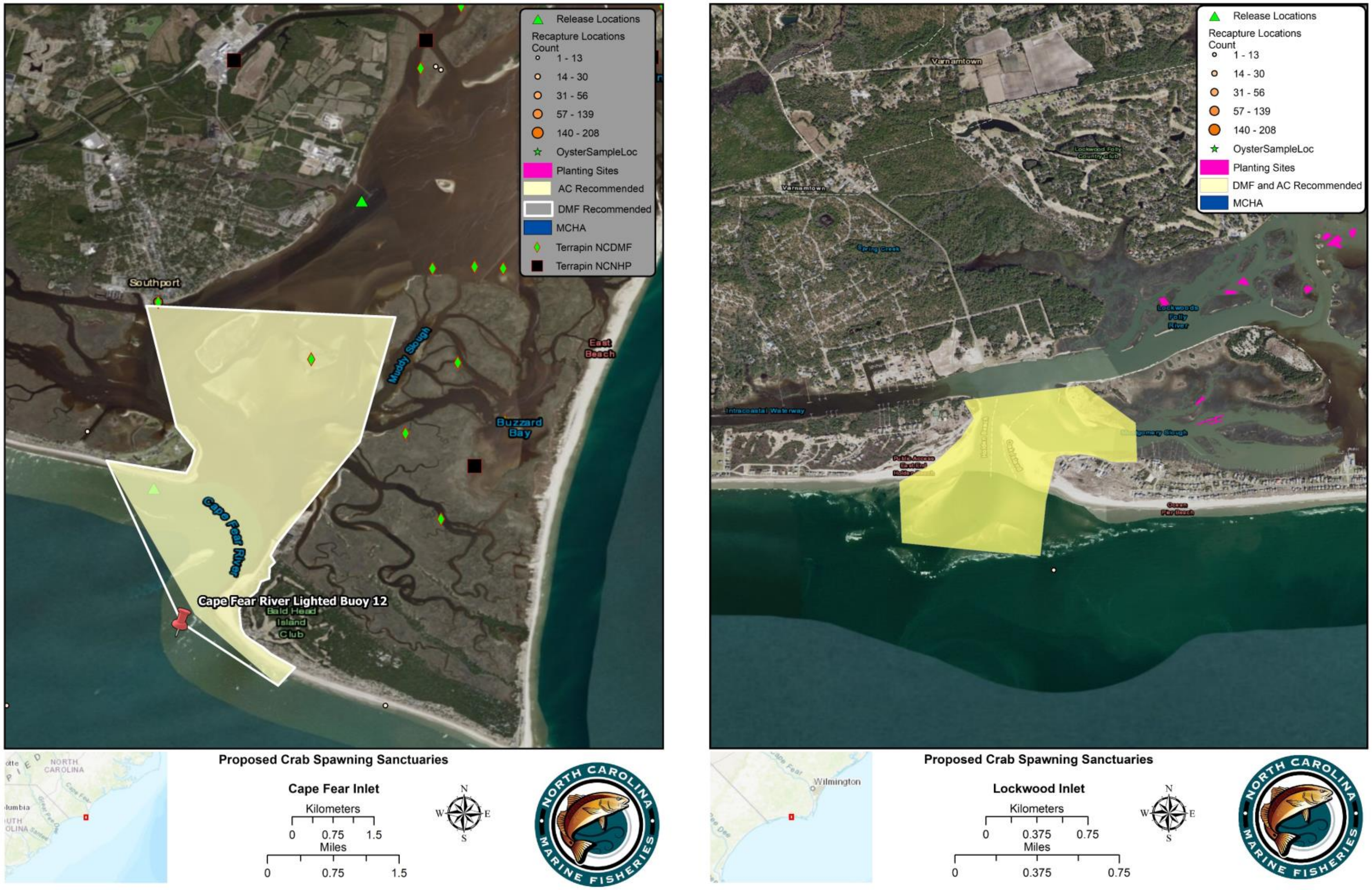

Figure 4.4.13. Proposed locations of new Crab Spawning Sanctuary boundaries for Cape Fear River and Lockwoods Folly inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

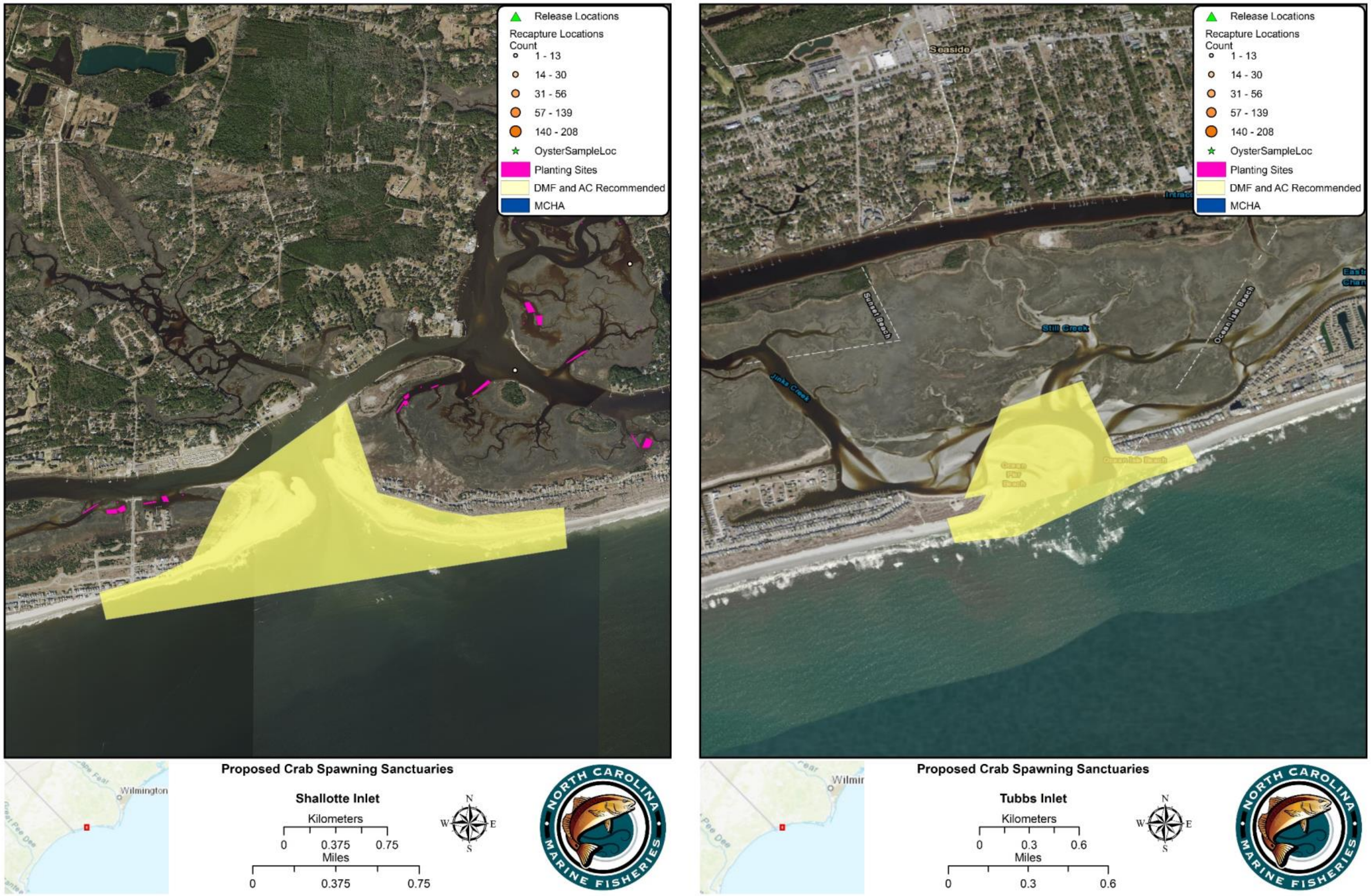

Figure 4.4.14. Proposed locations of new Crab Spawning Sanctuary boundaries for Shallotte and Tubbs inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

Designation of a Crab Spawning Sanctuary to Serve as a Migration Corridor

Another option to consider is the designation of crab spawning sanctuaries that act as migration corridors leading to inlets but are not themselves associated with an inlet. These would be areas that serve as migration pathways for mature female blue crabs during their migration to coastal inlets. A similar management strategy has been adopted in the Virginia waters of the Chesapeake Bay and was highly effective (Figure 4.4.15).

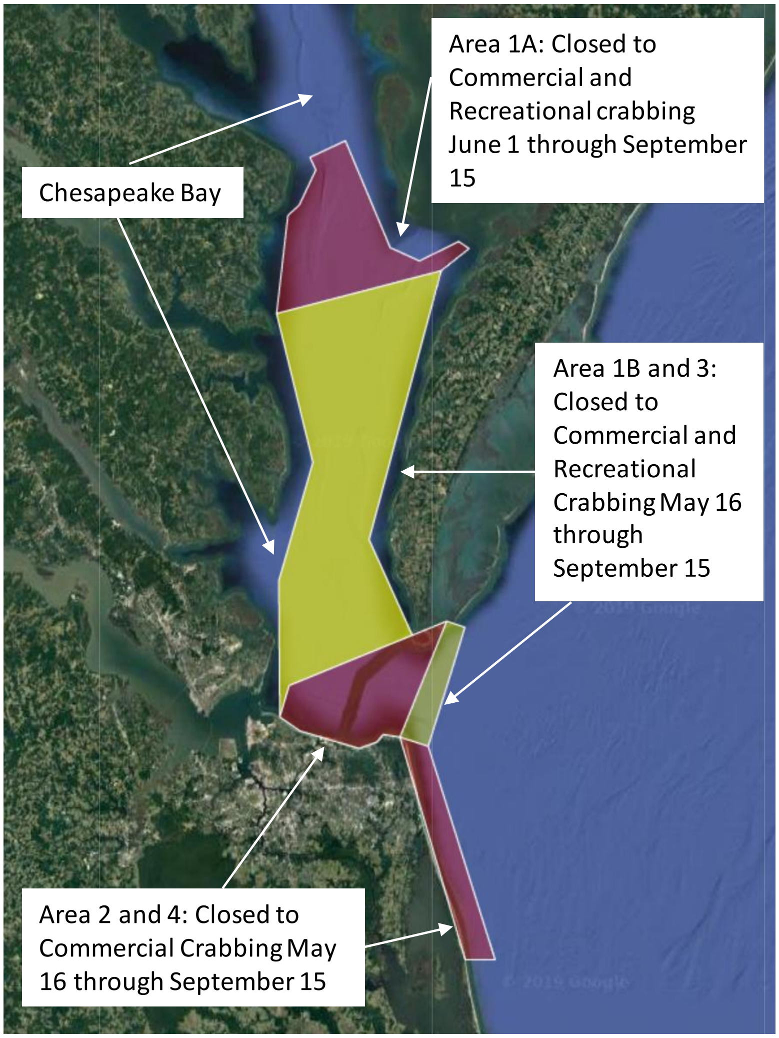

Figure 4.4.15. Virginia's Blue Crab Sanctuaries in the Chesapeake Bay including closure dates (https://webapps.mrc.virginia.gov/public/maps/crab_sanctuaries.php).

Although a distinct migratory corridor from mating sites in the Albemarle-Pamlico system to the spawning grounds was not detected by Eggleston et al. (8), there are several areas where mature female blue crabs are consistently more abundant. In 2002, results from the NCDMF Pamlico Sound Survey, supplemented by additional sampling in August, indicated that mature females were concentrated in northwest Pamlico Sound between Croatan Sound and Pamlico River in June. Mature female blue crabs were more than 50% less abundant in August and September but there was no clear migratory pattern of movement toward the inlets. The crabs might have moved into shallower areas and grass beds that could not be trawled. Mature female blue crabs are known to commonly occur in the seagrass beds behind the Outer Banks during the summer (G. Allen, NCDMF personal communications) which could account for part of their migratory path.

Looking at the entire time series for the Pamlico Sound Survey (1987 - 2017), mature female blue crabs are most concentrated in June north of Wysocking Bay and Buxton, across the entire sound (Figures 4.4.16 and 4.4.17). They are also concentrated to a lesser extent in Pungo and lower Pamlico rivers, and Croatan Sound. Additionally, mature female blue crabs occurred throughout the entire area in low numbers (1-50 crabs/trawl). In June, prevailing southwest winds in northern Pamlico Sound would help to push crabs toward Oregon Inlet. Females in the southern Pamlico Sound are closer to Ocracoke, Drum, and Barden inlets. In September, there was overall lower crab abundance and they were concentrated further north in Pamlico and Croatan sounds. In the southern portion of the sound, mature females were concentrated at the mouth of the Pamlico River.

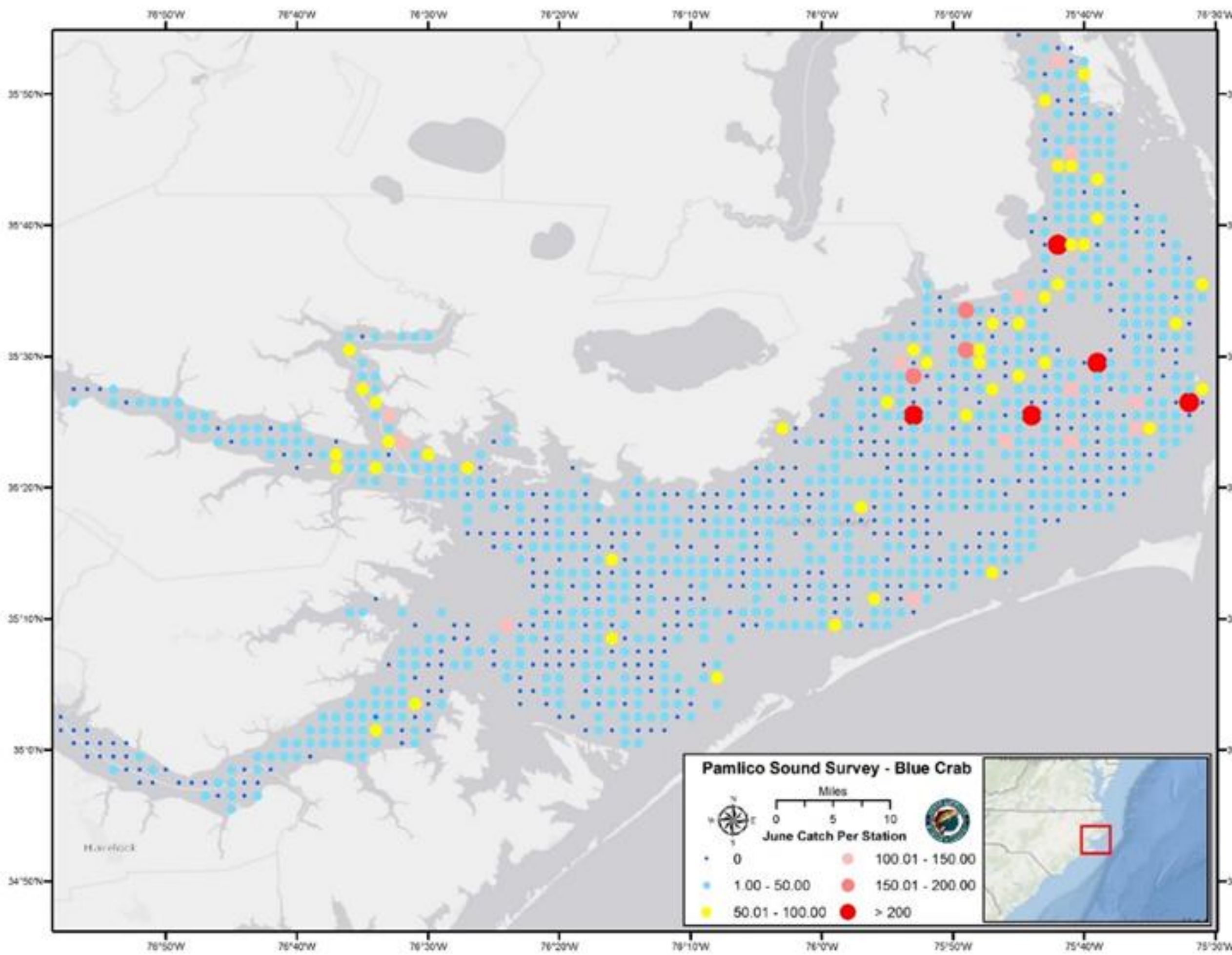

Figure 4.4.16. Total number of mature female blue crabs from Pamlico Sound Survey in June, 1987-2017.

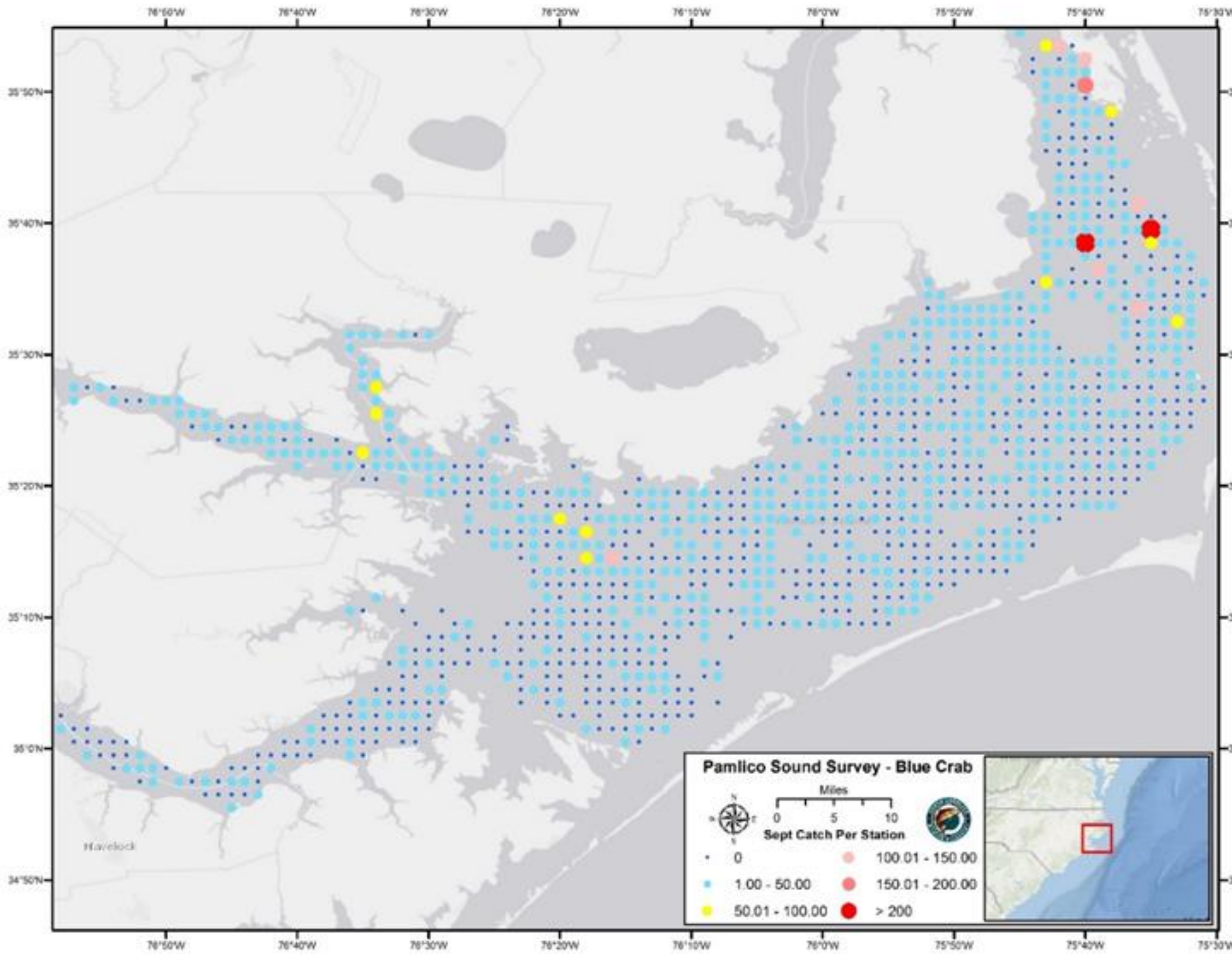

Figure 4.4.17. Total number of mature female blue crabs from Pamlico Sound Survey in September, 1987-2017.

To further evaluate where concentrations of mature females occur seasonally, a GIS tool, Optimal Hot Spot Analysis, was used. This GIS tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). This tool works by analyzing each feature (sampling grid) within the context of neighboring features. A feature with a high value is interesting but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum and when that difference is too large to be the result of random chance a statistically significant score results.

An Optimal Hot Spot Analysis was conducted by T. Udouj, SEAMAP, using mature female blue crab abundance data from the Pamlico Sound Survey. Figures 4.4.18 and 4.4.19 show the resulting maps for mature females in summer and fall months using the same Pamlico Sound Survey dataset as shown in Figures 4.4.16 and 4.4.17 of actual abundance data. Maps are symbolized based on the confidence level.

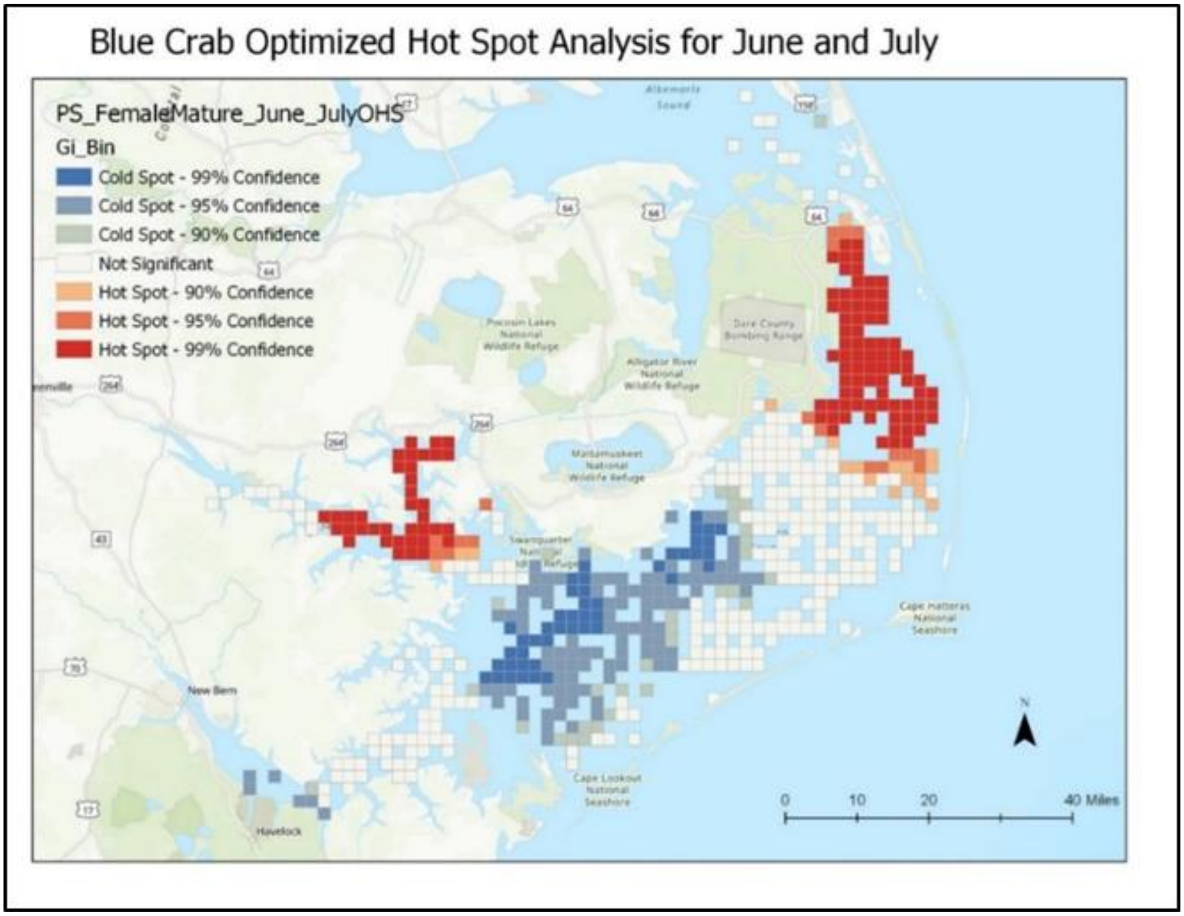

Figure 4.4.18. Areas with high confidence of having exceptionally high (red) or low (blue) numbers of mature female blue crabs from Pamlico Sound Survey in June and July, 1987-2017.

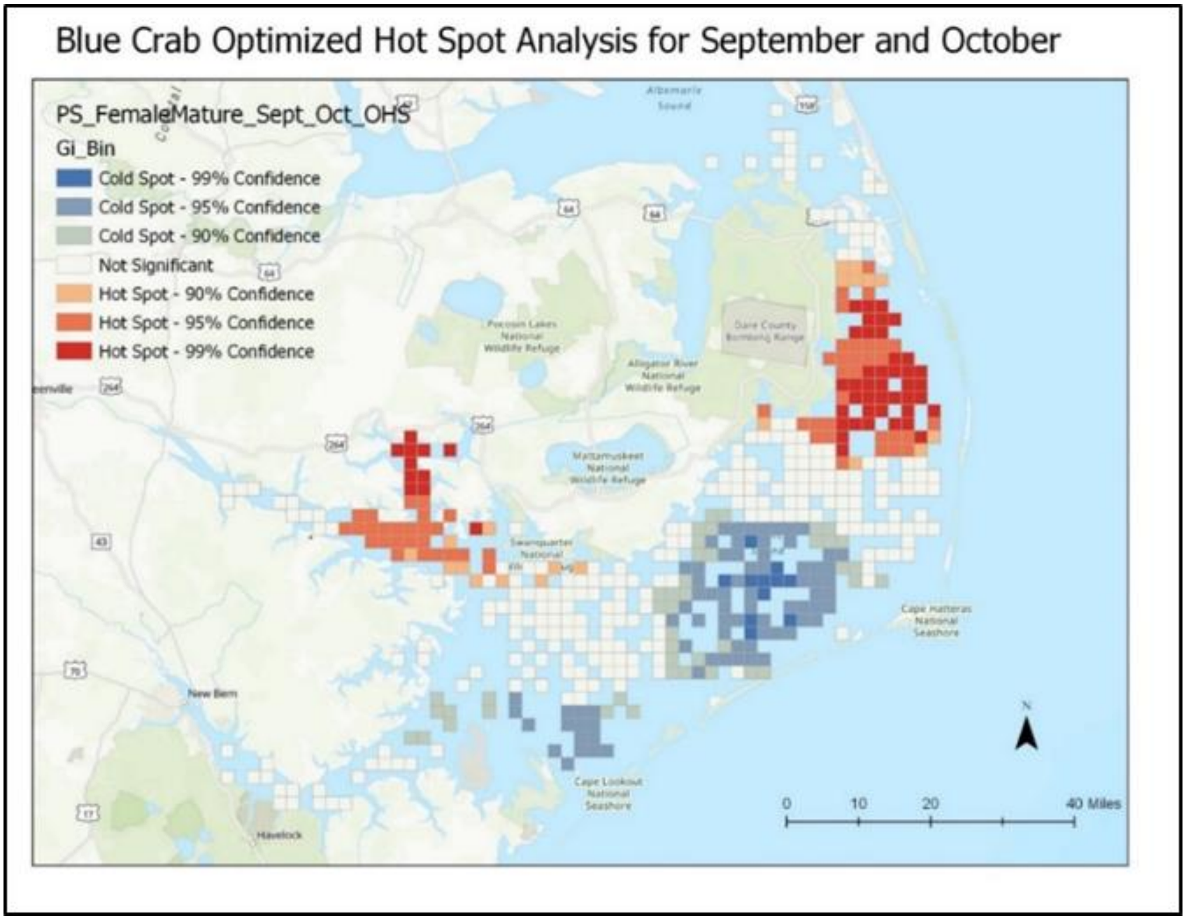

Figure 4.4.19. Areas with high confidence of having exceptionally high (red) or low (blue) numbers of mature female blue crabs from Pamlico Sound Survey in September-October, 1987-2017.

The results for June indicate there is a high probability (95-99%) of high concentrations of mature female blue crabs in Croatan and northern Pamlico sounds and in the Pungo River and lower Pamlico River (red areas; Figure 4.4.18). The results for September are similar, with the confidence values slightly lower (90%; Figure 4.4.19). Creation of a designated migration corridor in Croatan and northern Pamlico sounds, coinciding with the hot spots shown in Figures 4.4.18 and 4.4.19 is a management option to consider that is strongly supported by the data.

Advantages of an expanded sanctuary system and migration corridor include minimizing mortality and increasing protection of mature female blue crabs migrating to the spawning grounds. The economic impact to fishermen can be minimized by limiting the temporal and spatial extent of the protected area. Similarly, a migration corridor could be designated from the Pungo River to the nearest inlet spawning grounds. However, more information on mature female migration routes between the Pungo River, lower Pamlico River, and the inlets is needed to further define those migration corridors.

Data indicates Croatan Sound is a migration corridor for mature female blue crabs as they migrate out of Albemarle and Currituck sounds toward Oregon Inlet to spawn. In the Chesapeake Bay, Virginia opted for a summer closure in the deeper waters of the bay to help mature females migrate to the spawning grounds. A similar strategy could be adopted for the deeper waters of Croatan Sound to help protect mature females once they have mated and begin to migrate toward the spawning grounds. Figure 4.4.20 shows an area that could be designated as a migration corridor and how this area overlaps with the previously identified hot spots. The size of the example migration corridor is approximately 19,948 acres. The timing of landings peaks of hard, soft, and peeler blue crabs throughout the year may help indicate migration timing and indicate a seasonal closure period that would enhance the protection of mature female blue crabs in the waters of Croatan Sound (Tables 4.4.5 and 4.4.6).

Table 4.4.5. Commercial hard blue crab landings trends by Trip Ticket waterbody, 2012-2016.

Waterbody	Landings Peak	Largest Landings Increase	Landings Increase Percent*	Largest Landings Decrease	Landings Decrease Percent*
Chowan River	August	July-August	29	September-October	35.7
Perquimans River	August	July-August	11.2	September-October	12.1
Pasquotank River	August	May-June	9	October-November	11.3
Alligator River	October	April-May	7.9	October-November	10.8
Albemarle Sound	September	May-June	8	October-November	10.4
Currituck Sound	June	April-May	10.3	October-November	8.3
Croatan Sound	October	September-October	11	November-December	11.6
Roanoke Sound	October	September-October	11.2	November-December	12.0
Pamlico Sound	June	March-April	5.2	November-December	6.6

*The landings difference between months is the month to month difference in the percent of annual landings. For example, if January is 5% of the annual landings and February is 20% then the month to month difference in annual landings percent is 15%.

Table 4.4.6. Commercial soft and peeler blue crab landings trends by Trip Ticket waterbody, 2012-2016.

Waterbody	Landings Peak	Largest Landings Increase	Landings Increase Percent*	Largest Landings Decrease	Landings Decrease Percent*
Chowan River	September	July-August	36.1	September-October	60.3
Perquimans River	May/August	April-May	23.2	May-June	14.0
Pasquotank River	May	April-May	84.9	May-June	83.9
Alligator River	May	April-May	52.3	May-June	45.1
Albemarle Sound	May	May-June	58.6	May-June	55.0
Currituck Sound	May	April-May	64.3	May-June	72.9
Croatan Sound	May	April-May	61.2	May-June	68.9
Roanoke Sound	May	April-May	64.6	May-June	74.4
Pamlico Sound	May	April-May	44.8	May-June	58.9

*The landings difference between months is the month to month difference in the percent of annual landings. For example, if January is 5% of the annual landings and February is 20% then the month to month difference in annual landings is 15%.

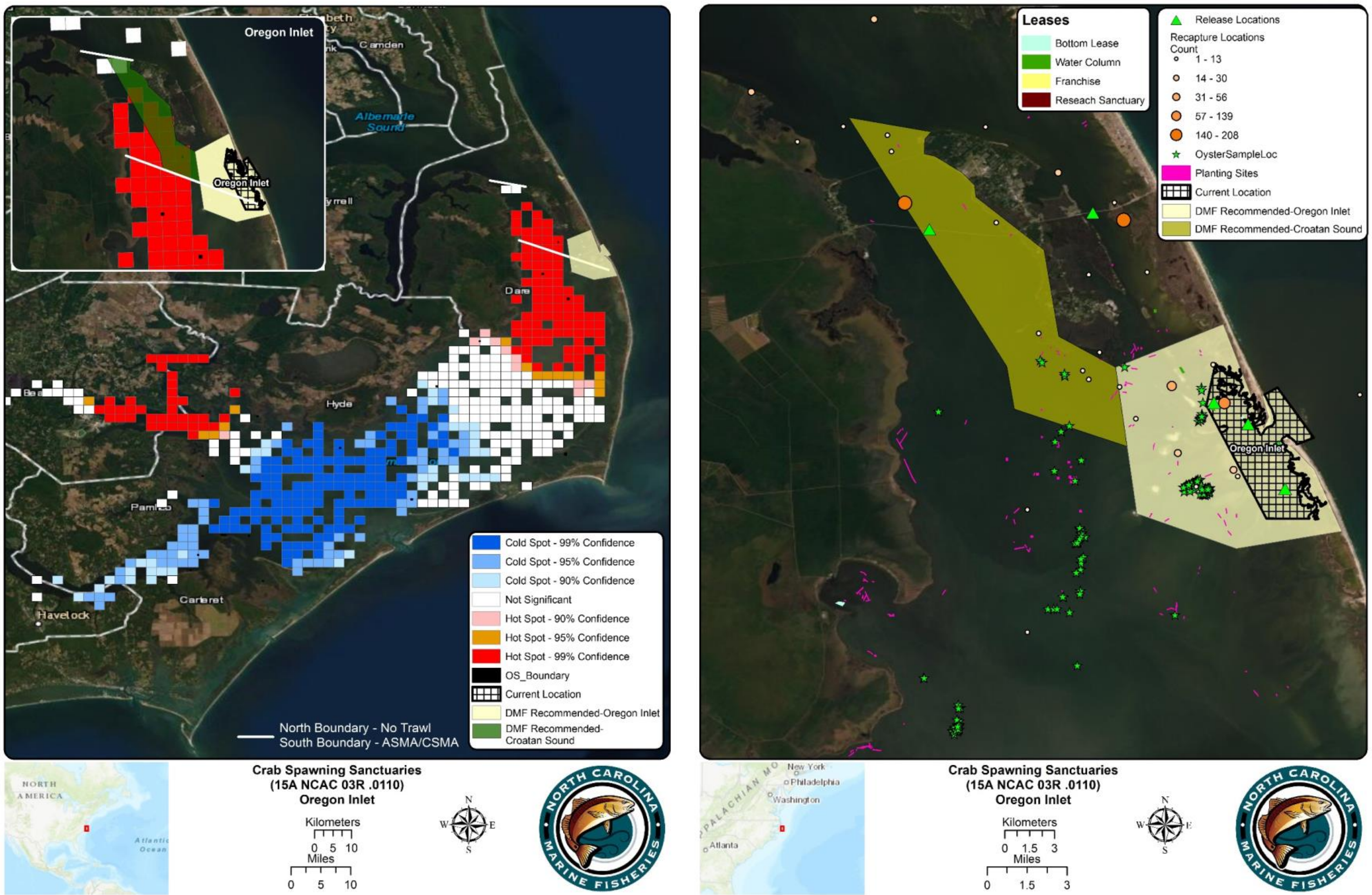

Figure 4.4.20. Location of proposed migration corridor through Croatan Sound in relation to the hot spot analysis results (left) and in relation to the NCDMF recommended Oregon Inlet crab spawning sanctuary expansion (right).

VI. PROPOSED RULES(S)

N/A

VII. MANAGEMENT OPTIONS AND IMPACTS

(+ Potential positive impact of action)
(- Potential negative impact of action)

Below are overarching positive and negative impacts for all options, specific impacts from an option may be found below that option.

- + Will protect additional mature female blue crabs from harvest to allow spawning to occur, potentially leading to increased population size
- + Will reduce some bycatch of finfish where new sanctuaries are established
- + Reduces damage or mortality of sponge crabs from incidental harvest
- – Potential for decreased harvest of blue crabs with economic loss to the fishery
- – Potential negative impact to the shrimp, oyster, and clam fisheries (depending on management strategy chosen)

1. Expand the boundaries of the five existing crab spawning sanctuaries

2. Establish new crab spawning sanctuaries at all inlets without a crab spawning sanctuary

3. Establish a crab spawning sanctuary to serve as a migration corridor in Croatan Sound

4. Close crab spawning sanctuaries around inlets from March 1 through October 31 to the use of trawls, pots, and mechanical methods for oysters or clams and to the taking of crabs with any commercial fishing equipment

5. Close crab spawning sanctuaries around inlets year-round to the use of trawls, pots, and mechanical methods for oysters or clams and to the taking of crabs with any commercial fishing equipment

VIII. RECOMMENDATION

<u>NCMFC Selected Management Strategy</u>

- Maintain existing boundaries for the Oregon, Hatteras, and Ocracoke inlets crab spawning sanctuaries; expand the existing crab spawning sanctuary in Barden Inlet and move the boundary of the Drum Inlet sanctuary to encompass Ophelia Inlet
    - Maintain existing mechanical gear restrictions and prohibition of crab harvest from March 1 -August 31
- Establish new crab spawning sanctuaries in Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Cape Fear River, Shallotte, Lockwoods Folly and Tubbs inlets
    - NCDMF recommended boundary approved for Cape Fear River Inlet sanctuary

- Closure period of March 1 through October 31 for new sanctuaries with the same gear and harvest restrictions as existing sanctuaries

NCMFC Summary
Mature female blue crabs require high-salinity waters to spawn, making inlets key habitats for their spawning activity. Blue crab mating peaks in April-June and August-September. Females then migrate to inlets, often overwintering in the soft bottom. Seasonal gear restrictions reduce negative impacts on migrating and spawning females. Sanctuaries are closed to the use of trawls, pots, mechanical methods for oysters and clams, and to the taking of crabs with any commercial fishing equipment. Five sanctuaries were established north of Cape Lookout in 1965. These sanctuaries are closed to mechanical methods and crab harvest March 1 - August 31. In Amendment 3, the NCMFC moved the boundary of Drum Inlet to encompass Ophelia Inlet and expanded the Barden Inlet sanctuary. Additionally, 14 new sanctuaries were established from Beaufort through Tubbs inlets. New sanctuaries are closed to mechanical methods, pots, and crab harvest March 1 - October 31. Initial May 1, 2020 implementation of the updated crab spawning sanctuaries is found in Proclamation M-7-2020.

See Appendix 4.7 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Blue Crab FMP Amendment 3.

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APPENDIX 4.5: ESTABLISH A FRAMEWORK TO IMPLEMENT THE USE OF TERRAPIN EXCLUDER DEVICES IN CRAB POTS

I. ISSUE

Establish a framework for developing proclamation use criteria and terrapin excluder specifications to reduce interactions of diamondback terrapins (*Malaclemys terrapin*) with crab pots.

II. ORIGINATION

North Carolina Marine Fisheries Commission (NCMFC) selected management strategy in Amendment 2 of the Blue Crab Fishery Management Plan.

III. BACKGROUND

The NCMFC adopted Amendment 2 of the North Carolina Blue Crab Fishery Management Plan (FMP) in November 2013 (1). In this plan, the NCMFC recognized diamondback terrapins as a wildlife resource in need of protection from crab pot fishing activities under its jurisdiction and sought to proactively implement conservation measures to prevent localized diamondback terrapin depletions or extirpations through incidental bycatch from current or future activity in the blue crab fishery. To implement this selected management strategy, the NCMFC granted proclamation authority for the director of the North Carolina Division of Marine Fisheries (NCDMF) to require terrapin excluder devices to be used in crab pots. This proclamation authority was placed in NCMFC Rule 15A NCAC 03L .0204(b), which became effective April 1, 2014. This rule states the Fisheries Director may, by proclamation, require the use of terrapin excluder devices in each funnel entrance in crab pots and impose the following restrictions concerning terrapin excluder devices: specify areas; specify time periods; and specify means and methods.

This issue paper develops proclamation issuance criteria necessary to implement the NCMFC management strategy and proposes a framework by which the NCDMF would determine discrete "diamondback terrapin management areas" (DTMAs) where all crab pots fished within would be required to use NCDMF approved terrapin excluder devices or modified pot designs. Once accepted by the NCMFC, this framework would be used to determine appropriate locations of DTMAs across coastal North Carolina. The issue of incidental capture of diamondback terrapins and use of excluders to prevent terrapin bycatch in crab pots in the North Carolina blue crab fishery is thoroughly reviewed in the issue paper "Diamondback Terrapin Interactions with the Blue Crab Pot Fishery" in sections 11.12 and 12.1.5.2 of the 2013 Blue Crab FMP Amendment 2

Diamondback terrapins were moved from "Near Threatened" to the greater risk category "Vulnerable" on the Red List of Threatened Species by the International Union for Conservation of Nature (IUCN) after their most recent assessment in 2018. Ongoing range-wide population declines due to accidental mortality as bycatch in commercial Blue Crab fisheries, and coastal habitat impacts due to development were cited as primary justifications for moving this species into the increased risk category. The North Carolina Wildlife Resources Commission (NCWRC) lists diamondback terrapin as a North Carolina species of "Special Concern" statewide and as a Federal "Species of Concern" in Dare, Pamlico and Carteret counties in NC. The status of "Special Concern" or "Species of Concern" does not specifically provide any special protection under the federal Endangered Species Act, however the federal status may be upgraded to "Threatened" or "Endangered" if natural or human-made factors are affecting its continued existence, or there is an inadequacy of existing regulatory mechanisms in place (e.g. unmitigated mortality from bycatch in crab pots). In February 2011, the NCWRC Nongame Wildlife Advisory Committee received a report from the Scientific Council on Amphibians and Reptiles which recommended the diamondback terrapin be listed as "Threatened" (2). This report, citing a large body of evidence from numerous studies, concluded incidental bycatch in crab pots is the most serious threat to diamondback terrapins in North Carolina (3; 4; 5; 6). Seafood Watch, one of the best-known seafood consumer awareness programs, gives the North Carolina blue crab fishery their lowest rating of "Avoid", stating that serious concerns about the lack of implementation of any regulations to protect diamondback terrapins from bycatch in crab pots are the primary reason for this poor rating (7).

Diamondback terrapins are found throughout North Carolina's high salinity coastal marshes; however, all coastal areas do not contain suitable terrapin habitat (8). Diamondback terrapins are long-lived, late to mature, and display relatively low fecundity (9). Delayed sexual maturity and low reproductive rates, coupled with long life spans and strong site fidelity, make this species susceptible to substantial population declines or even localized extirpations through the incidental bycatch and removal of a relatively low number of individuals from the population annually ([3; 6).

Genetic analysis (10) of diamondback terrapins sampled from Massachusetts to Texas suggests at least four major regional population groupings across this range, with North Carolina diamondback terrapins belonging to the Coastal Mid-Atlantic grouping. Although diamondback terrapins display high site fidelity, there is enough movement of individuals to maintain long term gene flow within these larger regional scales (10).

Several factors have been identified in determining the likelihood of diamondback terrapin bycatch in crab pots where crab fishing activities and diamondback terrapin occurrence overlap, such as: water depth and distance from shore (11; 12; 13; 14; 15), presence or dimensions of the excluder device (16; 17; 12; 15; 18; 19; 20; 21; 22), and the season which fishing occurs (11; 12; 13; 15; 23). Taking these factors into consideration, diamondback terrapin mortality from incidental bycatch in crab pots can be mitigated, reducing population impacts from localized and regional extinctions within North Carolina, and maintaining genetic connectivity across the Coastal Mid-Atlantic population.

Using the known factors affecting diamondback terrapin bycatch in crab pots, a highly targeted approach to reducing bycatch mortality with the least potential impact to the statewide blue crab fishery can be developed through the establishment of discrete regional DTMAs. This approach would be employed in lieu of either a statewide requirement for terrapin excluder devices to be used on all crab pots, or the prohibition of crab pots from specific areas. This issue is being addressed as part of Amendment 3 instead of being implemented in between FMP amendments due to the scheduled review of the blue crab FMP moved to 2016/2017 on the schedule by the NCMFC in August 2016.

IV. AUTHORITY

North Carolina General Statute
113-134 RULES
113-182 REGULATIONS OF FISHING AND FISHERIES
113-182.1 FISHERY MANAGEMENT PLANS
113-221.1 PROCLAMATIONS; EMERGENCY REVIEW
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03J .0301 POTS
15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS
15A NCAC 03L .0204 CRAB POTS

V. DISCUSSION

Step 1 Determine NCDMF approved terrapin excluder device types and sizes to be required

Multiple researchers across the range of diamondback terrapins have examined the effectiveness of terrapin excluder devices, also known as a bycatch reduction device, and their impact on the catch of blue crabs in the pot fishery. Table 4.5.1 provides a summary of these field studies by state. Across all studies the largest reduction in diamondback terrapin bycatch or the largest percent of potential diamondback terrapin exclusion typically occurred using terrapin excluder devices with the smallest vertical opening dimensions (Table 4.5.1). Impacts of terrapin excluder devices to crab catch ranged from 25.7% increased catch rates (24), to a 29% reduction in crab catch rates (25), as well as reduction in the average carapace width of crabs captured (20; 21). Numerous studies have also concluded that specific dimensions of terrapin excluder devices result in no significant reduction in size or catch rate of blue crabs when compared to control pots without terrapin excluder devices. However, some studies that did not find statistically significant differences in crab catch or sizes between control pots and pots with terrapin excluders did acknowledge a trend towards a reduced blue crab catch when terrapin excluders are in place (18; 19). Longer blue crab retention times in pots which employed excluder devices has been shown to mitigate catch rate impacts from lower numbers of crabs entering pots with excluders, resulting in no net loss in overall catch (20). However, from a theoretical modeling approach, which analyzed over 8,000 possible terrapin excluder dimensions (between 3.2 x 5.1 cm and 16 x 16 cm) compared to field collected morphometric dimension of terrapins, the overall excluder opening area followed by the diagonal excluder opening dimension were found to have the greatest predictive relationship with the exclusion of terrapins (22).

Shell height has often been concluded to be the determining dimension in the exclusion of diamondback terrapins from crab pots (16), and across multiple studies rectangular excluders with a vertical opening of 4 cm (1.6 in) or less have been the most effective (Table 4.5.1). In one

Virginia study, excluders which prevent terrapins from entering based on shell height were shown to allow the same number of terrapins to be captured in pots when compared to those which prevent entry based on shell width, however based on terrapin measurements simultaneously captured in pots without excluders, the devices which limited by shell width had greater potential exclusion (21). Requiring the use of a terrapin excluder device which restricts entry based on shell height, with a horizontal width less than 16 cm (6.3 in.), the typical width of a crab pot throat, may not result in any additional reduction in diamondback terrapin bycatch if the horizontal opening of the device is no larger than 4 cm (1.6 in.). In North Carolina a 4 x 16 cm (1.6 x 6.3 in.) excluder was shown to offer 100% reduction in potential terrapin capture (15). In South Carolina a relatively square shaped "SC design" excluder with a slightly curved top and bottom 5.1-6.4 x 7.3 cm (2-2.5 x 2.9 in.) which restricts entry based on shell width, would exclude 33% more terrapins than two other commonly tested excluder devices, 5 x 10 cm (2 x 3.9 in.) and 4.5 x 12 cm (1.8 x 4.7 in.), and by increasing the width of this device of 0.4 cm (0.2 in.) 99% of legal-size blue crab would be captured (22). Excluder devices made of 11-gague wire have been tested and have been recommended as an option in Virginia. However, crab pots with 11-gauge wire excluders do allow in large terrapins and wire excluders must be constructed of a gauge heavy enough to maintain rigidity (20). Pre-made plastic terrapin excluder devices may be purchased for approximately $0.50 from manufacturers such as Top-Me Products or made even more inexpensively with at least 10-gauge (or thicker) wire and hog rings (Figure 4.5.1).

The effect of excluder orientation has also been examined. In a controlled aquarium setting, McKee et al. (26) tested the effect of a 5 x 15.2 cm (2 x 6 in.) excluder device mounted both horizontally and vertically on diamondback terrapin entry to crab pots. They found that although there was a 17.5% reduction in diamondback terrapin entries into pots with a horizontally mounted excluder when compared to control pots without an excluder, this difference was not statistically significant. However, the vertically mounted excluder did result in significantly lower amount of diamondback terrapin pot entries and significantly longer entry times when compared to both control and pots with horizontally mounted excluders.

Diamondback terrapins display sexual dimorphism in size, with males not growing as large in shell height and length as females. Small diamondback terrapins of either sex are vulnerable to capture. However, females grow to a shell height which prevents them from entering typical crab pots by the time they reach eight years of age, with mature males possibly remaining vulnerable to pot entrapment throughout their life (4). This difference in growth rate and ultimate size difference between the sexes leaves young individuals (both sexes) and males more vulnerable to capture in crab pots when using some terrapin excluder devices. The selective removal of juveniles and males can lead to localized alterations in both population age structure and sex ratios, which can threaten the survival of the population (6). Due to geographic variation in diamondback terrapin body size, local evaluation of effective terrapin excluder device size may be required (27).

Hart and Crowder (15) in Jarrett Bay, off Core Sound, North Carolina, found using a 4 x 16 cm (1.6 x 6.3 in.) terrapin excluder device would have excluded 100% of all diamondback terrapins encountered during their research, however this would result in a 26.6% reduction in all legal sized male blue crabs captured, a 4.5 x 16 cm (1.8 x 6.3 in.) terrapin excluder device would have potentially excluded 77% of the total diamondback terrapins (100% female, 70% male) while reducing the legal male blue crab catch by 21.2%, and a 5 x 16 cm (2 x 6.3 in.) terrapin excluder device would have potentially excluded 28% of the total diamondback terrapins (50% female, 10% male). Based on pooled shell height data from diamondback terrapins captured by Southwood et al. (28) in Masonboro and Middle Sounds, North Carolina, a terrapin excluder device with a height of 4 cm (1.6 in.) would have excluded 91% of all diamondback terrapins (100% female, 80% male), a terrapin excluder device with a height of 4.5 cm (1.8 in.) would have excluded 51% of all diamondback terrapins (93% female, 0% male), and a terrapin excluder device with a height of 5 cm (2 cm) would have excluded 40% of the all diamondback terrapins (73% female, 0% male). Hart and Crowder (15) recommend the statewide adoption of a 4.5 cm (1.8 in.) height terrapin excluder device, as it offered high diamondback terrapin protection at a lower loss of blue crab catches. This size terrapin excluder device would have prevented the bycatch of 93% of female diamondback terrapins, but 0% of male diamondback terrapins sampled by Southwood et al (28). Chavez and Southwood Williard (19) examined the effects of "large" 5 x 15 cm (2 x 6 in.) and "small" 3.8 x 15 cm (1.5 x 6 in.) terrapin excluder devices on the catch of blue crab and diamondback terrapins at multiple sites around Beaufort, NC. They concluded that neither size resulted in a significant reduction in the number nor carapace width of blue crabs caught when compared to pots without terrapin excluder devices and resulted in a potential 86% (100% female, 0% male) to 100% reduction in diamondback terrapins captured, respectively. Chavez and Southwood Williard (19) did comment that although there was no statistically significant reduction in blue crab catch numbers, there is a trend toward catch reduction in pots fitted with the smaller terrapin excluder device.

As terrapin excluder devices have been demonstrated to reduce the efficiency of crab pots, crab fisherman may respond by increasing the total number of pots fished in an area to offset reductions in crab catch, resulting in an increase in the potential for diamondback terrapin interactions within the DTMAs. The possibility for increased localized crab pot effort as a response to the requirement to the use of terrapin excluder devices highlights the need to employ the most effective terrapin excluder devices.

The best current available data from diamondback terrapin and blue crab research should be used when considering the dimensions and type of excluder devices to be approved by NCDMF, and to be required for use in DTMAs. Arendt et al. (22), when modelling diamondback terrapin exclusion probabilities for the range of device dimensions tested and published in the literature since 1994, determined the 4 x 8 cm (1.6 x 3 in.) shell height limiting excluder followed by the "SC design" 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.) shell width limiting excluder to be the most effective at reducing the probability of diamondback terrapin entry into crab pots. These exclusion probabilities were calculated using dimensions from blue crabs and diamondback terrapins captured in South Carolina. As regional variation in morphometric length x width relationships as well as size distributions may exist for both blue crabs and diamondback terrapins, the exact reductions in diamondback terrapin capture and impacts to blue crab catch may likely be site specific for each excluder dimension. In North Carolina field studies, excluders which limit based on shell height, with an opening no more than 4 cm vertical height and no more than 16 cm horizontal width (1.6 x 6.3 in.) have been shown to offer the greatest protection to both male and female diamondback terrapins, however this size excluder device is shown to impact the blue crab catch in pots where they are employed (see Table 4.5.1). When examining the size distribution of diamondback terrapins captured in North Carolina by researchers at the University of North Carolina Wilmington, both a height limiting excluder with a vertical opening of no greater than 4 cm (1.6 in.) and the "SC design" 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.) shell width limiting excluder would appear to prevent the bycatch of the majority and most frequent size ranges of terrapins captured in North Carolina (Figure 4.5.2) and should be approved for use as bycatch reduction methods in any proposed DTMAs. Terrapin excluders will be securely affixed by at least each of the four corners of the device in each funnel opening of the crab pot, in a manner that restricts the maximum dimensions of any opening in the funnel to that of the internal opening dimensions of the approve excluder device employed (Figure 4.5.3).

To allow for collaboration between stakeholders, NCDMF a diamondback terrapin bycatch reduction workgroup consisting of North Carolina fisherman, academic researchers, and fishery managers should be formed. This workgroup may review and test existing excluder devices or work in partnership to examine novel bycatch reduction designs to minimize the impact to blue crab catch while reducing terrapin bycatch. Recommendations on additional excluder devices or modified pot designs by the workgroup will be considered for approved use in DTMAs by the NCDMF in consultation with the Shellfish/Crustacean Advisory Committee. To be considered for approval by the NCDMF, the other devices or modified pot designs must be shown to reduce impacts to blue crab catch or cost to fisherman and maintain a level of diamondback terrapin protection offered by existing approved excluder devices.

Step 1 Summary:
Criteria defines the **approved terrapin excluder device types and sizes required in crab pots fished within designated DTMAs**. The following terrapin excluder devices shall be considered approved for use in DTMAs: any shell height limiting excluders made from at least 10-gauge galvanized wire and hog rings with an internal opening no larger than 4 x 16 cm (1.6 x 6.3 in.) height by width; any pre-made plastic shell height limiting excluder devices with an internal opening no larger than 4 x 16 cm (1.6 x 6.3 in.) height by width; or the pre-made plastic shell width limiting "SC design" measuring 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.; Figure 4.5.1). Terrapin excluders will be securely affixed by at least each of the four corners of the device in each funnel opening of the crab pot, in a manner that restricts the maximum dimensions of any opening in the funnel. A separate terrapin excluder device would not be required in a crab pot fished within a DTMA if all funnel openings in that pot were modified to measure no larger than the maximum internal opening of an approved excluder device, and the funnel openings are made rigid in a manner to maintain these dimensions. A diamondback terrapin bycatch reduction workgroup of fisherman, academic researchers, and managers will be created. Additional or alternative terrapin excluder devices or modified pot designs recommended through the workgroup may be approved by NCDMF, in consultation with the Shellfish/Crustacean Advisory Committee, provided they have been shown to reduce impacts to blue crab catch or cost to fisherman and maintain the level of diamondback terrapin protection offered by the terrapin excluder devices initially approved and listed above. A revision to the current FMP Amendment will be developed as additional devices are approved.

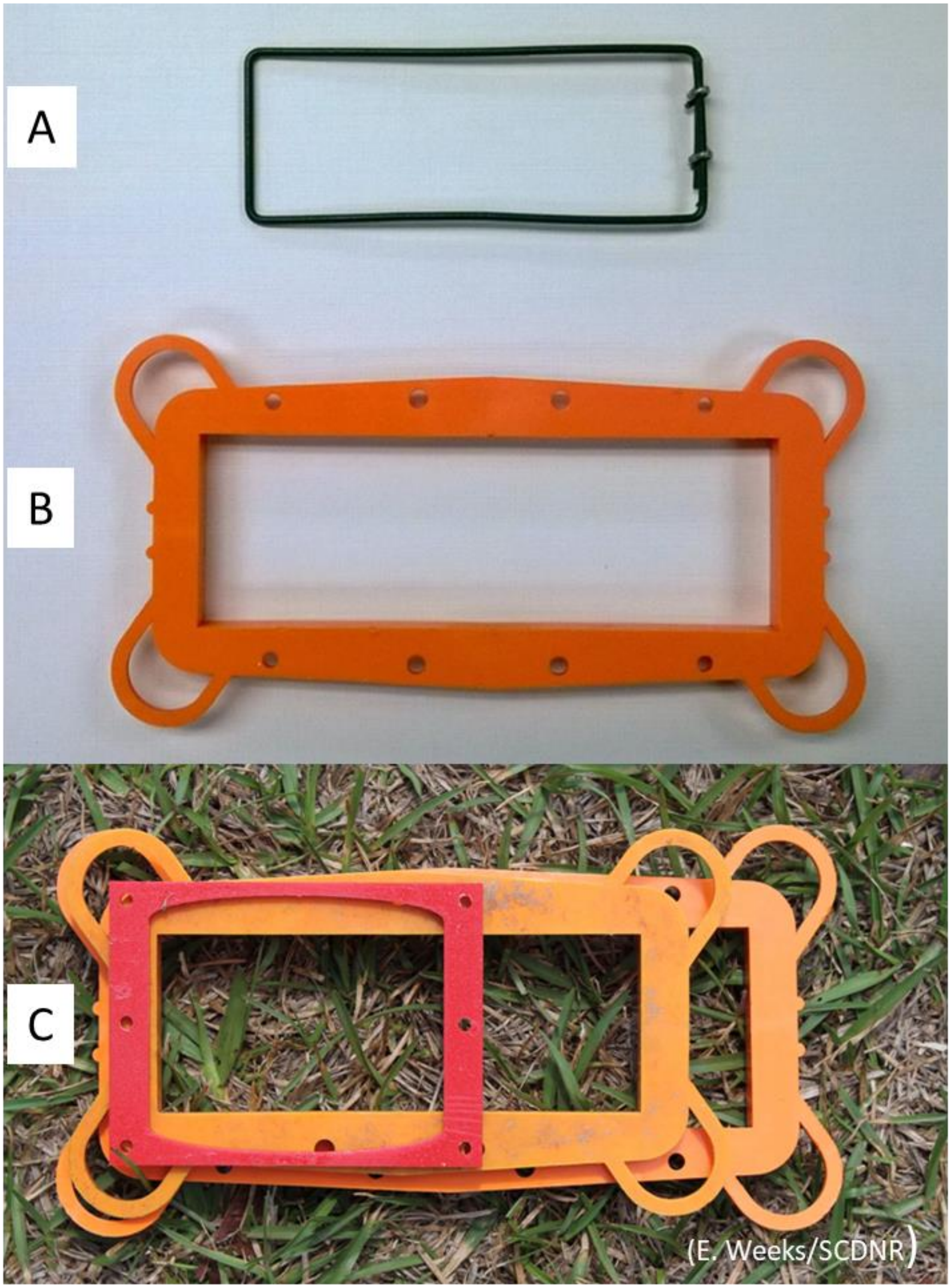

Figure 4.5.1. Examples of terrapin excluder devices for use in crab pots include: (A) wire and hog ring excluder made by a crab pot manufacturer, (B) premade plastic excluder made by Top-Me Products, (C) plastic "SC design" excluder, a shell width limiting device (red) shown on top of two premade plastic shell height limiting devices (photo credit: E. Weeks/SCDNR).

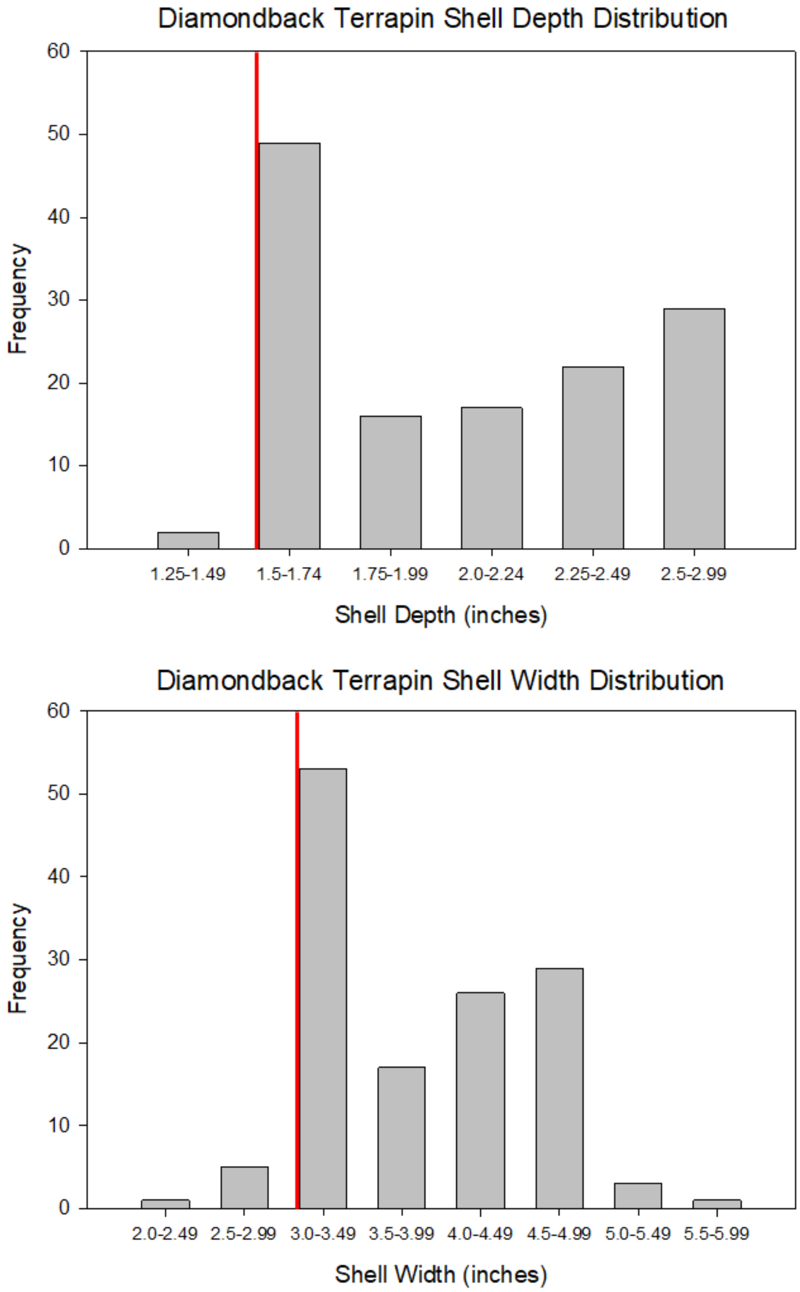

Figure 4.5.2. Distribution of shell depth and height for diamondback terrapins (n = 135) in coastal North Carolina. Data compiled by Dr. Amanda Williard (Department of Biology and Marine Biology, University of North Carolina Wilmington). These data represent field records for terrapins captured by seine at multiple sites (Figure 8 Island, Masonboro Island, Bald Head Island, and Beaufort) 2008 to 2018. Vertical red lines approximate potential exclusion of individuals in the size frequency bins to the right of the line; in the upper panel by a height limiting excluder design with a vertical opening of no greater than 4 cm (1.6 in.) and by a shell width limiting "SC design" 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.) in the lower panel.

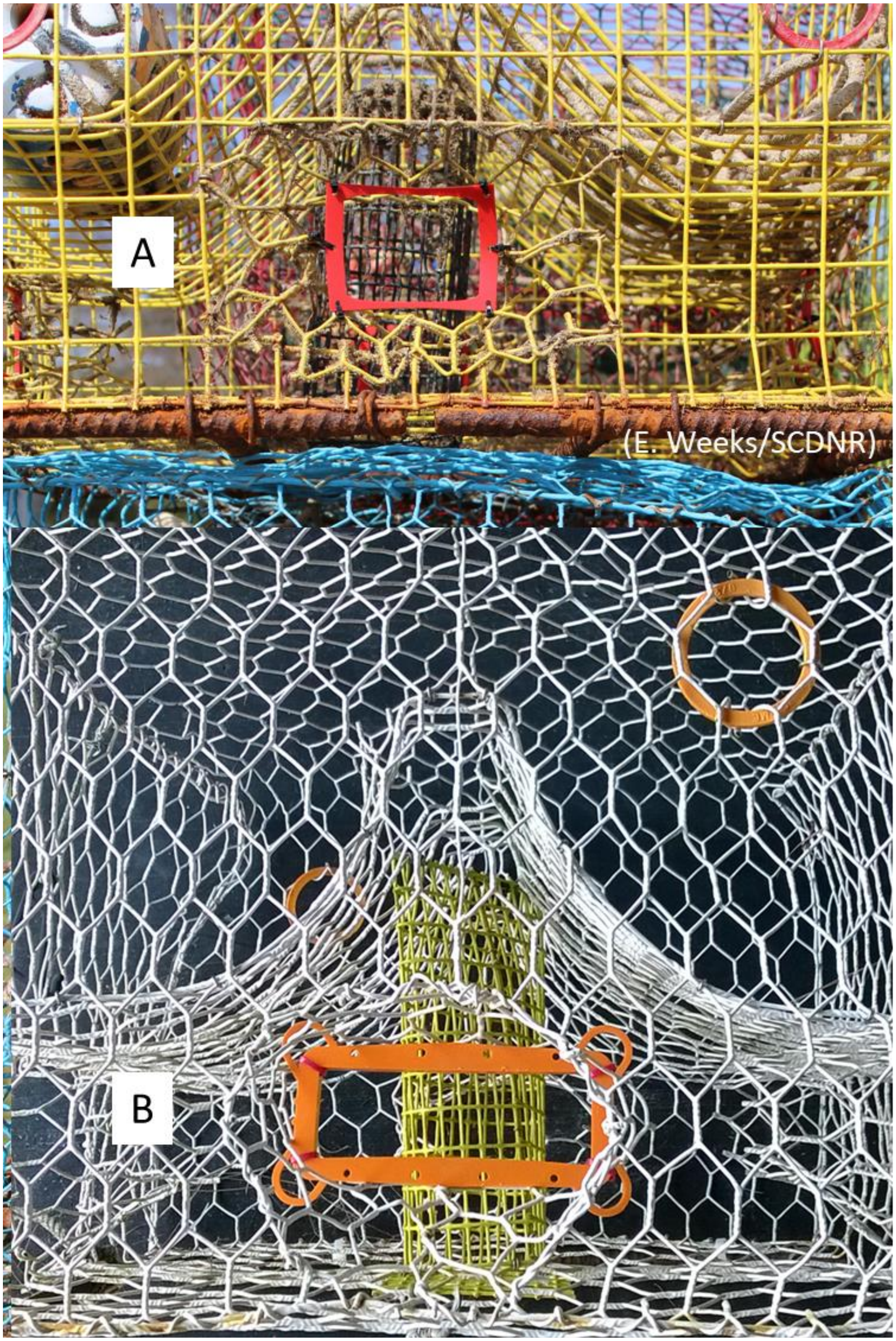

Figure 4.5.3. Premade plastic diamondback terrapin excluder devices shown inside one entrance funnel opening of crab pots. (A) The "SC design" shell width limiting excluder. (B) A shell height limiting excluder.

Table 4.5.1. Summary results of field studies examining effectiveness of different terrapin excluder device dimensions and impacts to blue crab catch. A * signifies no diamondback terrapins were caught in the study.

Location	Reference	Excluder Dimensions (cm; height x width)	Impact to Diamondback Terrapin Bycatch	Impact to Blue Crab Catch
NJ	Mazarella 1994 (29)	5 x 10	93% reduction	No significant difference
NJ	Wood 1997 (30)	5 x 10	90% reduction	11% increase in catch rates
		4.5 x 10	100% reduction	9% increase in catch rates
DE	Cole and Helser 2001 (17)	5 x 10	59% reduction	No significant change in number
		4.5 x 12	66% reduction	12% reduction in legal crabs
		3.8 x 12	100% reduction	26% reduction in legal crabs
MD	Roosenburg and Green 2000 (16)	5 x 10	47% reduction	No significant effect on size or number
		4.5 x 12	82% reduction	No significant effect on size or number
		4 x 10	100% reduction	Significant reduction in size and number
VA	Rook et al. 2010 (31)	4.5 x 12	96% reduction	No significant effect on size or number
VA	Upperman et al. 2014 (18)	5 x 15.2	75% potential exclusion	No significant effect on size or number
		4.5 x 12	96% potential exclusion	Significant reduction in size and number
VA	Corso et al. 2017 (20)	5.1 x 15.2	83% reduction	No significant effect on number
				Significant reduction in size (1mm)
VA	Grubbs et al. 2017 (21)	5.1 x 15.3	87% reduction	No significant reduction in catch rate
				Significant reduction in size (2mm)
		6.4 x 7.3	87% reduction	No significant reduction in catch rate
				Significant reduction in size (2mm)
NC	Grant 1997 (25)	5 x 10	75% reduction	19% reduction
		4 x 12	100% reduction	29% reduction
NC	Thorpe and Likos 2008 (32)	5 x 12	*	5.7% reduction
		5 x 10	*	18.2% reduction
NC	Hart and Crowder 2011 (15)	5 x 16	28% potential exclusion	5.7% reduction in legal male crabs
		4.5 x 16	77% potential exclusion	21.2% reduction in legal male crabs
		4 x 16	100% potential exclusion	26.6% reduction in legal male crabs
NC	Chavez and Southwood Williard 2017	5 x 15	86% potential exclusion	No significant reduction in size or number

Location	Reference	Excluder Dimensions (cm; height x width)	Impact to Diamondback Terrapin Bycatch	Impact to Blue Crab Catch
	(19)	3.8 x 15	100% potential exclusion	No significant reduction in size or number
SC	Grubbs et al. 2017 (21)	5.1 x 15.3	*	No significant reduction in catch rate
				Significant reduction in size (1mm)
		6.4 x 7.3	*	Significant reduction in catch rate
				Significant reduction in size (2mm)
GA	Belcher and Sheirling 2007 (33)	5 x 16	98% reduction	7% reduction in number
FL	Butler and Heinrich 2007 (34)	4.5 x 12	73.2% reduction	No significant effect on size or number
LA	Guillory and Prejean 1998 (24)	5 x 10	*	25.7% increase in overall catch rate

Step 2 Determine dates when terrapin excluder devices will be required

Diamondback terrapins display seasonal differences in habitat use and are known to enter a state of torpor during the winter months. Hardin and Southwood Williard (23) observed radio tagged diamondback terrapins begin exiting the water column and burrow into the marsh mud once water temperatures drop below 20 degrees Celsius (68 °F) during October in Masonboro Sound, North Carolina. They then observed diamondback terrapins resuming activity in April as water temperatures rose. The peak catch of diamondback terrapins in crab pots was seasonal in South Carolina, with the majority of captures occurring during April and May (11). These elevated catches were probably associated with post hibernation feeding and reproductive activity (11). In Jarrett Bay, North Carolina, Hart and Crowder (15) observed all diamondback terrapin interactions with blue crab pots during April and May. In Masonboro Sound, North Carolina, Alford and Southwood Williard (35) sampled modified "tall" crab pots from May to late October. These modified pots are greater in height than standard commercial crab pots, which allows entrapped diamondback terrapins access to air during all tidal phases to prevent drowning mortality. During those months, 27 diamondback terrapins were captured with May having the highest capture rate with 12 diamondback terrapins, followed by June and July with five and four, respectively. There were no captures in August, four in September, and two in October. In southeastern North Carolina, the diamondback terrapin "active season", was determined to be between April 1 and October 31 by observing the movement and activity patterns of radio tagged diamondback terrapins (23). NCDMF has recently encountered active diamondback terrapins in sampling programs in March, during higher than average spring temperatures. Allowing fisherman to use crab pots without terrapin excluder devices during the dormant season (November 1 – February 28) in DTMAs should not result in significant bycatch of diamondback terrapins, however, this may result in crab pots without terrapin excluder devices being lost and becoming "ghost pots" within DTMAs. Though not baited, these "ghost pots" may continue to cause bycatch mortality (36).

Step 2 Summary:
As peak captures of diamondback terrapins in crab pots occur in early spring as individuals emerge and become active, it is important to account for annual variably in spring temperature and have terrapin excluder devices employed before diamondback terrapins become active. Based on NCDMF interactions and research conducted in North Carolina, **terrapin excluder devices shall be used in designated DTMAs from March 1 through October 31** to cover the entirety of the potential diamondback terrapin active season to limit diamondback terrapin bycatch. Both commercial and recreational crab pots would be required to use terrapin excluder devices when fishing in DTMA's during the diamondback terrapin active season.

Step 3 Identify the zone of potential diamondback terrapin interaction with crab pots

Crab pots are one of the most widely distributed fishing gears in the state, occurring throughout all coastal and joint fishing waters. Diamondback terrapins typically spend most of their lives in shallow water adjacent to tidal wetlands, resulting in only a small portion of the area used in the crab pot fishery spatially intersecting with diamondback terrapin habitat (27). The water depths in these nearshore diamondback terrapin habitat areas generally range from < 1 m to 3 m (< 3.3 to 9.8 ft.). In a cooperative research study between crab fishermen and the management agency in South Carolina, 1,913 crab pots set between 0 and 9 m (0 and 29.5 ft.) in depth were sampled. All captured diamondback terrapins were from pots set at depths < 5 m (16.4 ft.), and 97% were captured in pots at depths < 3 m (9.8 ft.; 14).

Thorpe et al. (13) notes that at a study site in Carteret County, North Carolina, all pots sampled were set greater than 91 m (298.6 ft.) from shore and no diamondback terrapins were caught. However, at sites in Brunswick County, North Carolina, all pots were set within 4.5 m to 91 m (14.8 to 298.6 ft.) from shore, resulting in nine diamondback terrapins being caught (all of which were captured < 13 m (42.7 ft.) from shore). Grant (25), at three estuarine sites in North Carolina, showed significant reductions in diamondback terrapin captures as distance from shore increased. The majority of diamondback terrapins (84.5%) were captured less than 25 m (82 ft.) from shore and 15.5% were taken between 26 and 50 m (85.3 and 164 ft.) offshore. None were captured in pots more than 50 m (164 ft.) from shore. In Jarrett Bay (Core Sound), North Carolina, all diamondback terrapin captures occurred within 321 m (1,053.1 ft.) of the shoreline, with 90% occurring 250 m (820.2 ft.) or less from the shore and 76% occurring 150 m (492.1 ft.) or less from the shore (15).

From these studies, it can be inferred the potential zone of most diamondback terrapin interactions with crab pots in North Carolina are areas that are both less than 250 m (820.2 ft.) from any shoreline and less than 3 m (9.8 ft.) deep at low tide. However, using a specific depth and distance from shore as a metric for requiring a terrapin excluder device may be problematic to effectively enforce, due to changing tides and currents. The designation of discrete DTMAs, which primarily contain habitats less than this depth and distance from shore, are easier to enforce as a way to implement a terrapin excluder device requirement in the crab pots.

Using these parameters (less than 250 m (820.2 ft.) from any shoreline, and less than 3 m (9.8 ft.) deep at low tide), a GIS layer was created for the state and mapped to identify regions that meet both criteria (Figure 4.5.4). A narrow band of potential interaction zone lies immediately behind nearly all of the outer banks and other barrier islands. The southern shoreline of Albemarle Sound, as well as locations in the Alligator and Pasquotank rivers also contain areas of potential interaction zone. Broader regions of potential interaction zones occur within Currituck Sound, as well as the lower Newport River and areas around Fort Macon and Beaufort. The widest and most continuous area identified as a potential interaction zone occurs primarily in New Hanover and Brunswick counties in the coastal areas spanning from Figure 8 Island to Bald Head Island.

Step 3 Summary:
Based on currently available data, **areas both less than 250 m from any shoreline and less than 3 m deep at low tide shall be generally identified as areas of potential overlap between diamondback terrapins and the crab pot fishery**. These criteria may be revised by the division as additional research becomes available.

<u>Step 4 Validate diamondback terrapin presence and overlap with zone of potential crab pot interaction</u>

Several sampling programs conducted by the NCDMF encounter diamondback terrapins. These programs include several fishery-independent trawl surveys, a commercial gill net observer program, and fishery-independent gill net survey. These sampling programs are all conducted in brackish marsh areas across the state which contain possible suitable diamondback terrapin habitat. From 1970 to 2017, a total of 649 individual diamondback terrapin interactions were documented. Due to multiple captures at one site, or fixed station designs in sampling programs, these 649 individual diamondback terrapins have been recorded from 173 unique locations throughout coastal North Carolina.

The North Carolina Natural Heritage Program (NCNHP), maintains a database of natural resource information which also contains diamondback terrapin distribution information. This database is used by government agencies, industry, the military, and conservation groups to make economic development, infrastructure, and land conservation decisions. NCNHP diamondback terrapin distribution data comes from reported sightings as well as compiled data from published research, such as the Southwood Williard and Harden (28) postcard survey. Plotting both the NCDMF sampling program diamondback terrapin interactions and the NCNHP data over the potential interaction zone, visually illustrates the areas statewide where diamondback terrapin populations are likely to occur as bycatch in the crab pot fishery (Figure 4.5.5).

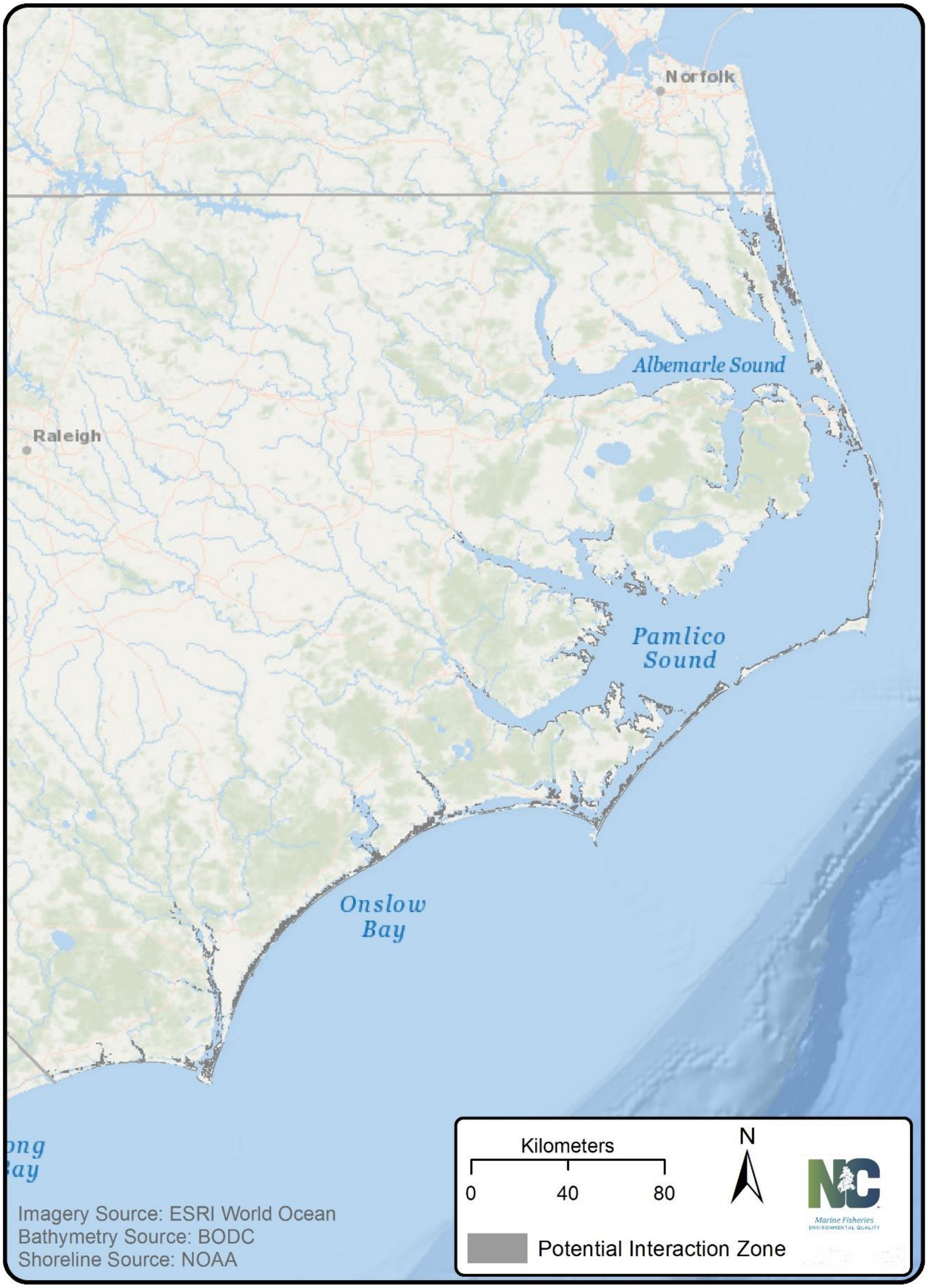

Figure 4.5.4. A map of coastal North Carolina showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots.

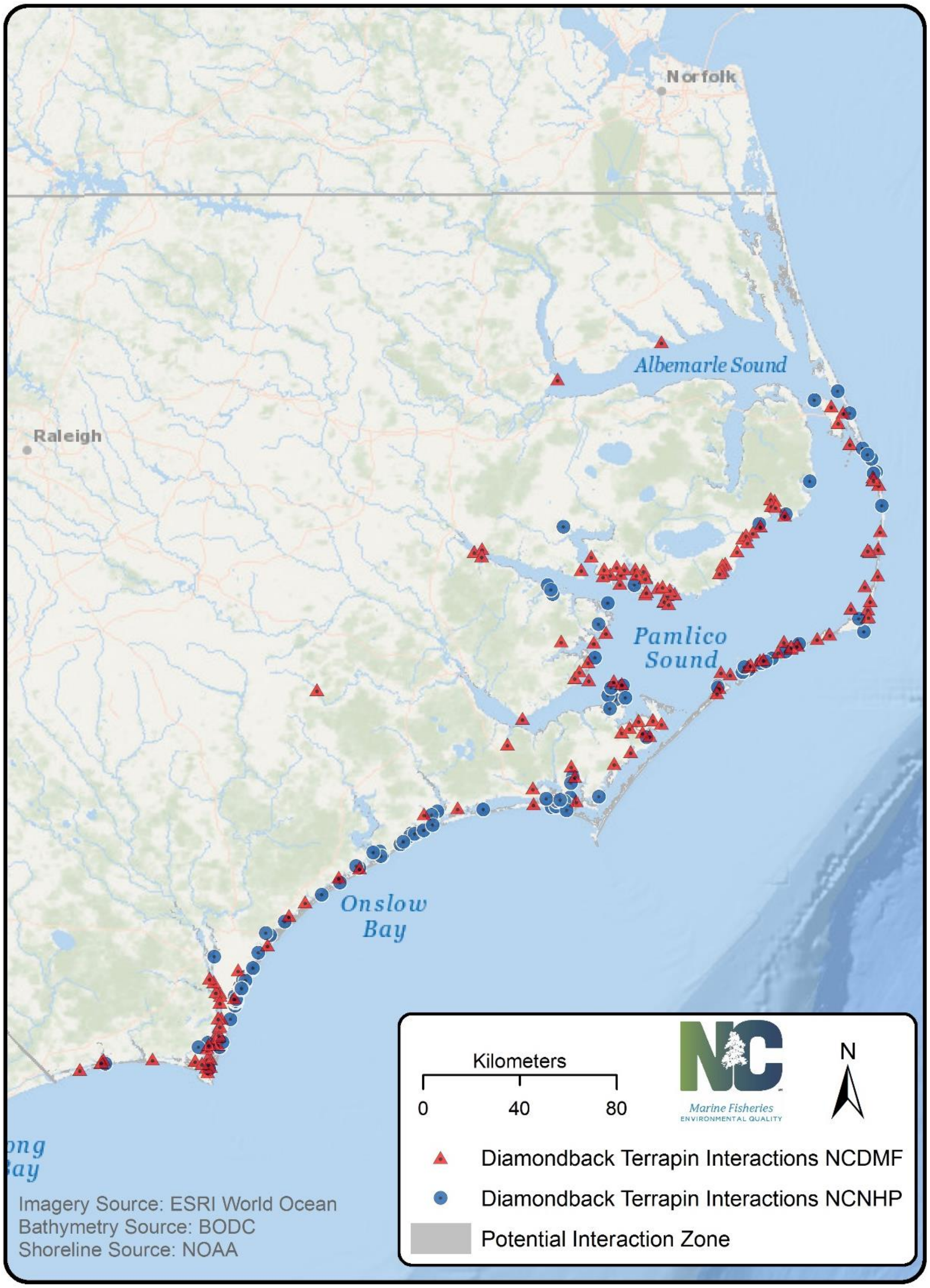

Figure 4.5.5. A map of coastal North Carolina showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

Diamondback terrapin distribution is observed primarily from Roanoke Island to the South Carolina line. There are two NCDMF interactions recorded in Albemarle Sound, however the rest of the region north of Roanoke Island does not have any diamondback terrapin occurrences documented in either the NCDMF or NCNHP datasets. The area in Currituck Sound which is highlighted as a potential interaction zone, also does not have documented diamondback terrapin occurrences. Some areas which have been identified as potential interaction zones with overlapping diamondback terrapin occurrences include: the areas immediately behind the Outer Banks from Roanoke Island to Portsmouth Island, portions of western Pamlico Sound, the lower Newport River, areas around Fort Macon and Beaufort, as well as the areas from Figure 8 Island to Bald Head Island. Detailed regional maps highlight the potential interaction zone and known terrapin occurrences for these areas (Figures 4.5.6 – 4.5.10). The region spanning from Wrightsville Beach to the lower Cape Fear River shows one of the relatively wide areas of potential interaction zone which also has numerous documented diamondback terrapin occurrences in the state (Figure 4.5.10).

Step 4 Summary:
Diamondback terrapin presence and overlap with the zone of potential crab pot interaction shall be verified by the division using any of the following: data from the NCDMF, NCNHP, other agencies, universities, and peer-reviewed published literature.

Step 5 Determine appropriate Diamondback Terrapin Management Area boundaries

The creation of DTMAs would focus the use of terrapin excluder devices or approved modified pot designs to essentially create sanctuary areas where diamondback terrapins would otherwise suffer mortality due to incidental catch in crab pots. Crab pots will not be banned in these areas, however, to successfully ensure the maintenance of diamondback terrapin populations within these areas and to have them possibly serve as long-term regional source populations, bycatch should be reduced to low levels within the DTMA's.

Diamondback terrapins have been observed to have relatively small home ranges in North Carolina. In Core Sound, average radio tagged terrapin home range size was calculated to be 3.05 km2 (1.18 mi.2), with a maximum observed home range of 7.41 km2 (2.86 mi.2) (37). In coastal New Hanover County, NC, the maximum straight-line travel distance of radio tagged terrapins observed was 1.20 km (0.75 mi.) for individuals captured in Masonboro Sound, and 1.05 km (0.65 mi.) for Figure 8 Island marshes (23). The size of a DTMA should at a minimum allow for the protection of the entire possible home range size of the target local terrapin population and may include adjacent unoccupied suitable terrapin habitat to allow for population recovery. The smallest size to likely be an effective DTMA should encompass the largest known home range of diamondback terrapin in NC, or cover 7.41 km2 (2.86 mi.2, 1830 acres) of suitable terrapin habitat.

For an area to be considered for designation as a DTMA, a diamondback terrapin population must be documented (e.g., NCDMF, NCNHP, or other agency or university data), as well as being identified as a potential area for diamondback terrapin interactions with crab pots (via the GIS depth and distance layer). The boundaries should incorporate a significant portion of the selected region identified as a potential interaction zone. Natural boundaries for ease of marking, compliance, and enforcement should be considered, however the design should minimize including any waterbody area not designated as potential interaction zone. Boundaries of other existing natural or conservation areas may also be used to identify DTMAs to aid in public compliance and simplify enforcement and marking, provided they are comprised primarily of the potential interaction zone.

Examples of possible types of natural or conservation areas in NC include State Natural Areas, National Estuarine Research Reserves, National Wildlife Refuges, and National Seashores. State Natural Areas have been designated by the North Carolina Division of Parks and Recreation to protect areas sensitive to human activities and preserve and protect areas of scientific, aesthetic, or ecological value. The National Estuarine Research Reserve System (NERR) is a network of protected areas across the United States which protects coastal and estuarine habitats for long-term research, education, and coastal conservation. The National Wildlife Refuge system (NWRS), and National Seashores are networks of federally managed lands and waters within the United States recognized and protected for their natural value. Considering these types of management areas when delineating DTMAs allows NCDMF to use boundaries that have been previously established and marked and serves as additional justification for requiring terrapin excluder devices in areas which have been independently determined as environmentally sensitive or important habitats for the protection of wildlife. An increase in crab pot density of one pot per creek is associated with a 74.6% decline in terrapin count, when estimating the impact of unmodified crab pots on a refuge wide scale (38). The use of terrapin excluder devices or modified pot designs for the reduction of diamondback terrapin mortality in crab pots would align with the wildlife protection and conservation goals of the various managing agencies for these existing designated areas. Negative impacts from crab pot mortality and low potential rates of recolonization may prevent maintaining ongoing populations of diamondback terrapins in refuges or reserves unless diamondback terrapin loss through bycatch is minimized (38).

Step 5 Summary:
Boundaries of DTMAs shall be drawn to incorporate a significant portion of the potential interaction zone containing verified population(s) of diamondback terrapins and to minimize the inclusion of areas not identified in the potential interaction zone. Boundaries of preexisting natural or conservation areas may be used as DTMA boundaries to aid in public compliance, simplify enforcement, and to support the conservation goals of these areas.

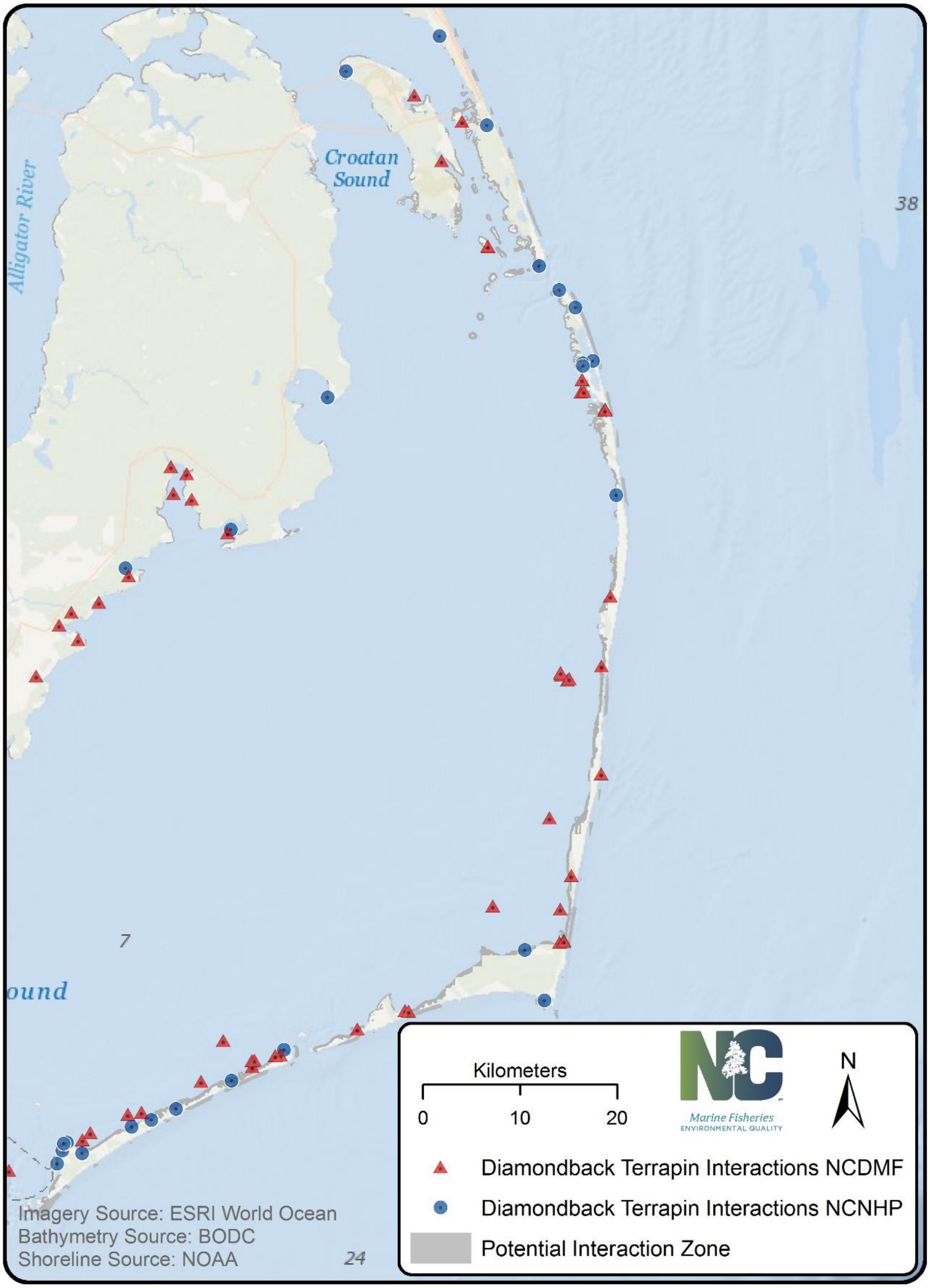

Figure 4.5.6. A map of eastern Pamlico Sound showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

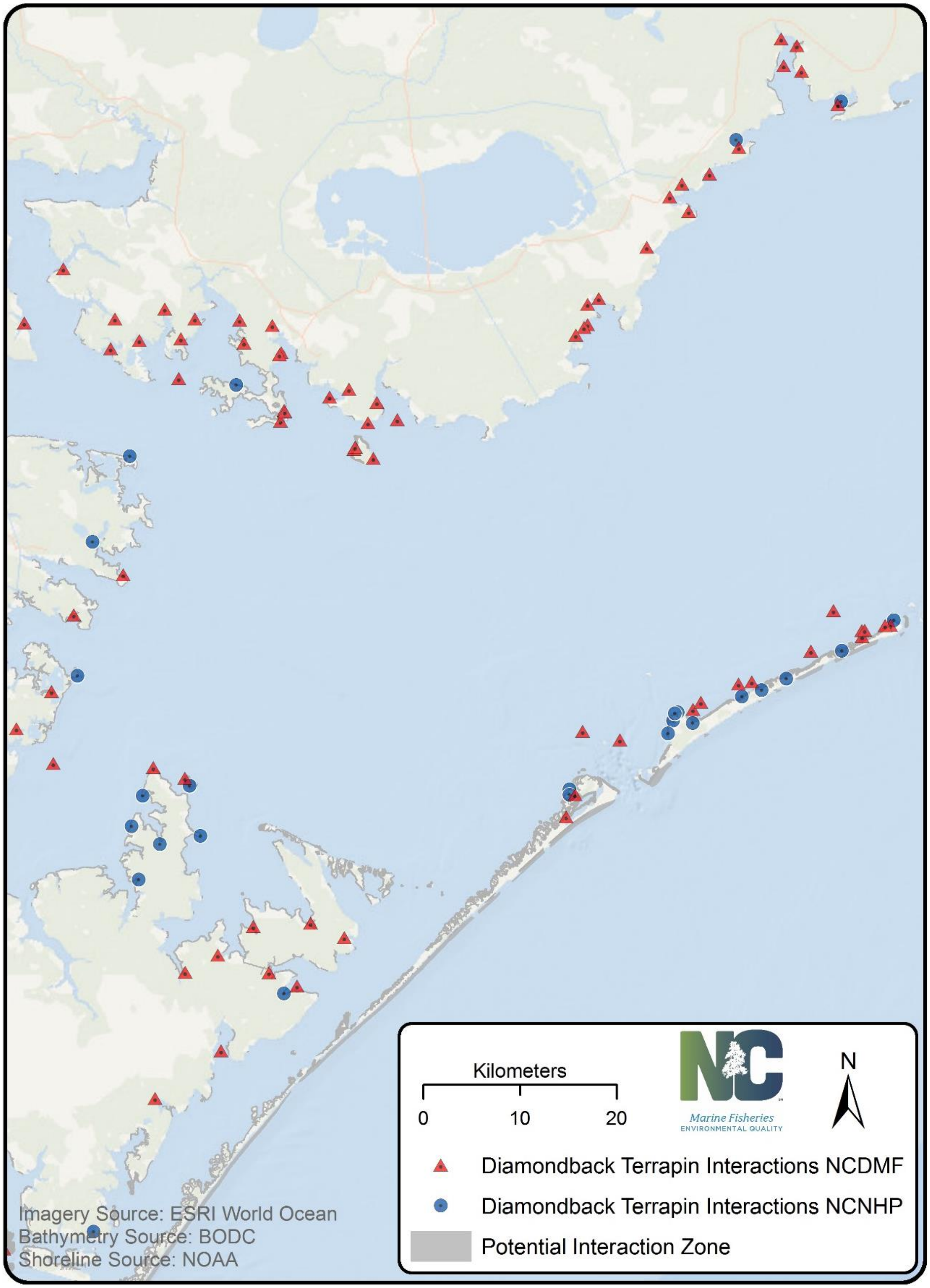

Figure 4.5.7. A map of western Pamlico Sound showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

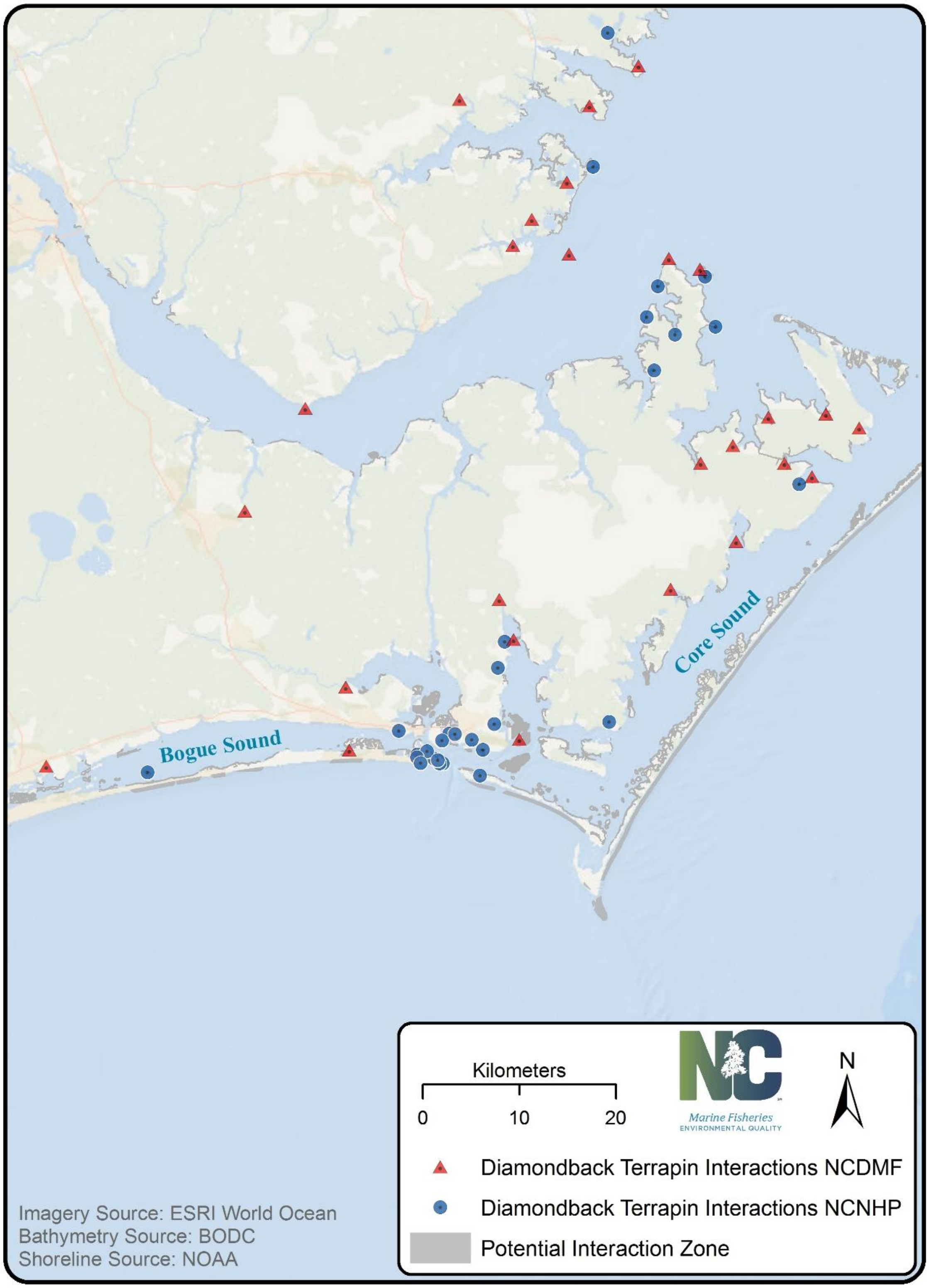

Figure 4.5.8. A map of Core and Bogue sounds showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

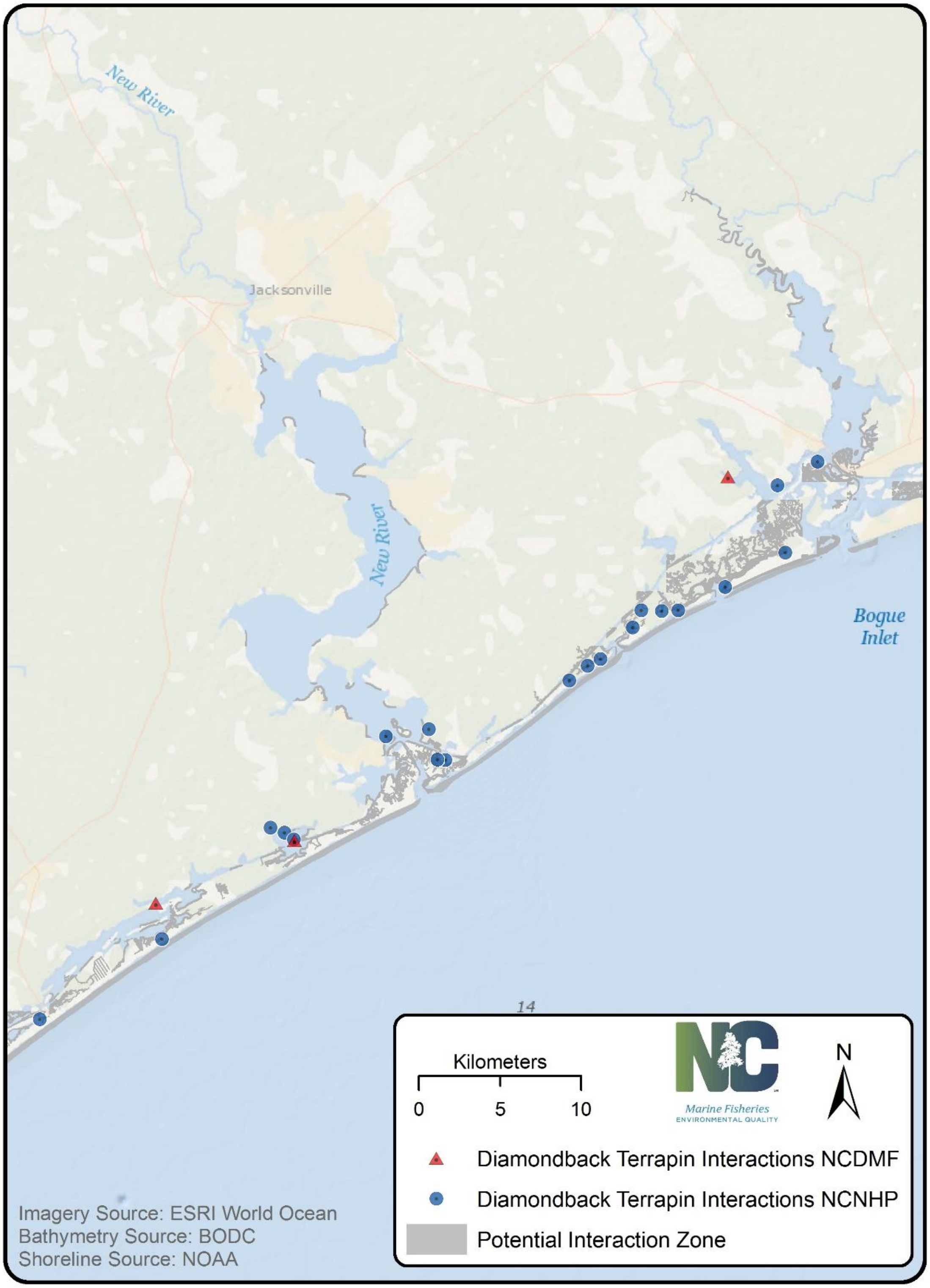

Figure 4.5.9. A map of coastal Onslow and Pender counties showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

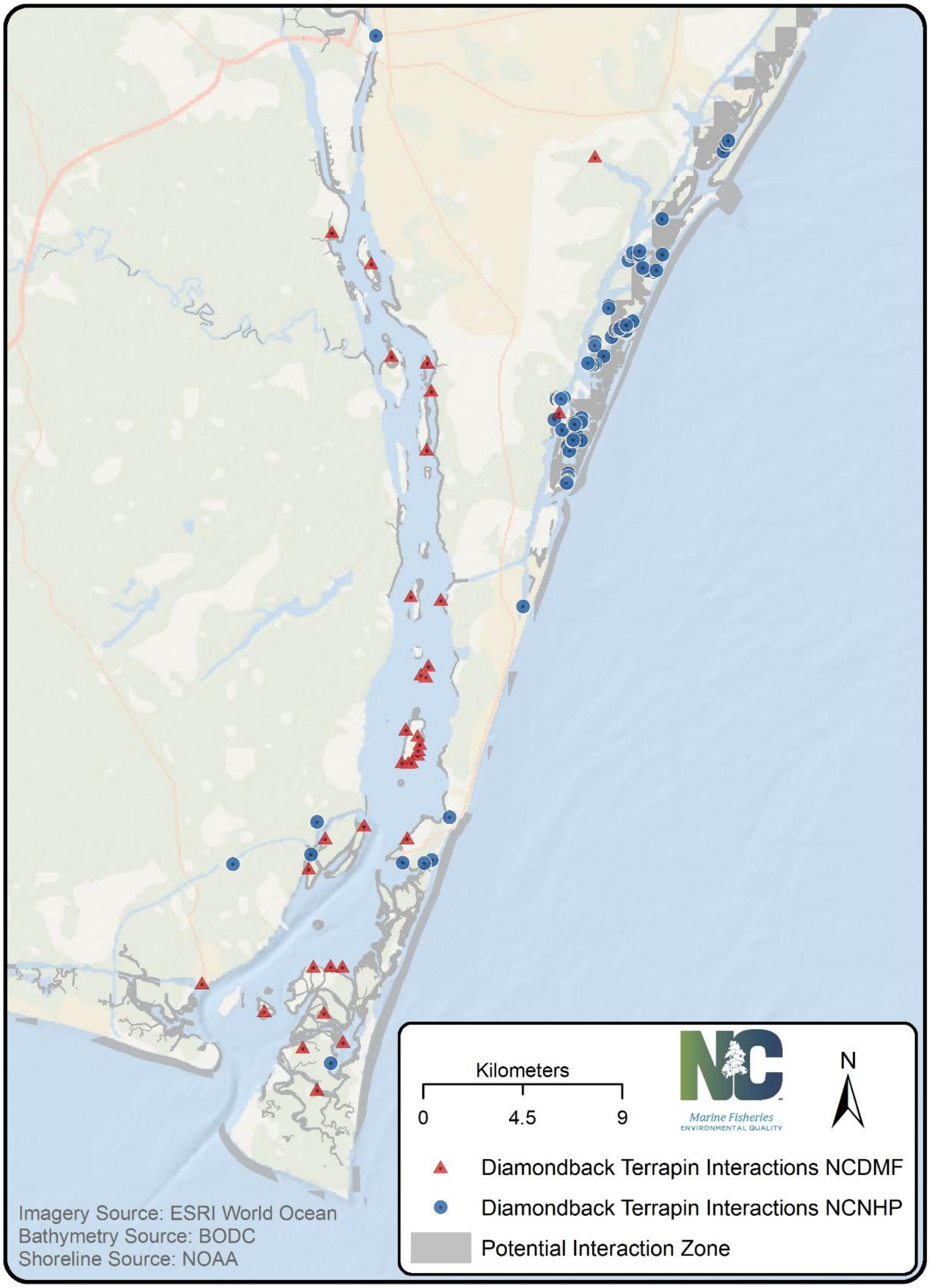

Figure 4.5.10. A map of coastal New Hanover and Brunswick counties showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

Step 6 Initial issue paper detailing the proposed DTMA will be presented to the appropriate regional committee and receive public comment

Once an area has been identified by NCDMF as an area where establishing a DTMA would be appropriate, an issue paper containing the following details of the proposed DTMA will be produced:

1) Map and coordinates of the proposed DTMA boundaries.
2) Cited sources and summary of diamondback terrapin presence data within the proposed DTMA.
3) Information on any existing natural or conservation areas overlapping with the proposed DTMA.
4) Data on the local blue crab fishery within the proposed DTMA.

Maps of the proposed DTMA shall illustrate the proposed DTMA boundaries as well as display the GIS layer illustrating the zone of potential diamondback terrapin interaction with crab pots based on the established depth and distance from shore criteria. Maps will also overlay known locations where diamondback terrapins have been documented to occur. Source data for diamondback terrapin occurrences from publications will be summarized and cited as references. Data sources such as NCDMF biological database records or NCNHP will also be listed and referenced. If the proposed location is within an existing natural or conservation areas (e.g. NERR, NWRS), supporting information about or from the managing agency will be provided. Participation and landings (pounds and value) data from the local blue crab pot fishery to be impacted by the proposed DTMA will also be presented and will include data for other marketable bycatch species. However, under certain situations limited data may be available to the public due to confidentiality requirements with landings data involving small numbers (less than three individuals) of fishery participants.

This initial issue paper will be presented to the appropriate regional advisory committee for their input and to receive public comment (see Attachment 1 **for an example** of how issue papers will be formatted). Public notice will be made via a press release and the issue paper describing the proposed DTMA will be made available with a 30-day public comment period open prior to the regional advisory committee meeting. Due to restrictions, public comment will not be accepted via email. Online and physical mail options will be included in the public comment period. The division will contact local crab fishermen in the area to be impacted as well as regional diamondback terrapin researchers for their comment. The division will take into consideration advisory committee and public comments and may work with fishermen and researchers to modify the proposed DTMA boundaries to maintain protections for diamondback terrapins while minimizing impacts to the local blue crab fishery. **See Step 7 added from the NCMFC motion for adoption of Amendment 3**.

Step 6 Summary:
The division shall produce an initial issue paper (with the information outlined above and structured as the example in Attachment 1), present the information to the appropriate regional advisory committee for their input, inform the public of the proposed DTMA via a press release,

hold a 30-day public comment period, and contact local crab fishermen and diamondback terrapin researchers for their comment.

<u>Step 7 NCMFC review documents and take action to adopt, adopt with modification, or deny proposed DTMA</u>

Once advisory committee and public comment have been received, the division may create a revised issue paper to address topics including but not limited to boundary lines, area adjustments, additional impacts, and other public concerns within a reasonable vicinity of the proposed DTMA under consideration. Boundary modifications may be necessary in the revised issue paper due to division concerns brought forth by public comment, further internal review, and to best address public understanding for compliance. The public will be notified that the proposed DTMA is under NCMFC consideration via a press release for the NCMFC business meeting. The division will present documents including but not limited to a revised issue paper, justification for any necessary changes, public comments, and AC and NCDMF recommendations to the NCMFC at their next regularly scheduled meeting. The NCMFC will take into account advisory committee and NCDMF recommendations, as well as public comments in order to establish DTMA boundaries that maintain protections for diamondback terrapins while minimizing impacts to the local blue crab fishery. The NCMFC will adopt, modify for adoption, or deny the proposed DTMA.

Step 7 summary:
The division shall produce a revised issue paper which will be presented along with supporting documents to the NCMFC for action. The NCMFC shall adopt, modify for adoption, or deny the proposed DTMA.

<u>Step 8 Implement adopted DTMA by proclamation and incorporate the finalized issue paper as a revision to the FMP</u>

Proclamation issuance by the NCDMF director shall depend on NCMFC adoption of the proposed DTMA. If the NCMFC moved to adopt a DTMA, the division director shall issue a proclamation designating this DTMA under the authority granted in NCMFC Rule 15A NCAC 03L .0204. The proclamation will contain GPS coordinates, a description of the boundaries, a map illustrating the DTMA, and outline of terrapin excluder device requirements. This proclamation will specify, as stated in framework steps one and two, that all commercial and recreational hard or peeler crab pots fished within the DTMA shall be required to properly use at least one of the NCDMF approved terrapin excluder types in all funnels from March 1 through October 31. Additionally, the proclamation text will be drafted to maximize public understanding, compliance, and enforceability. Minor boundary modifications to the approved DTMA may be made when drafting proclamation text, however no separate new areas may be added to the DTMA at this time. Any area modifications will be made to better establish points that are both clear to the public and/or enforceable within the vicinity of NCMFC approved boundary lines.

The division will issue the DTMA proclamation at least one month prior to the effective date, and when possible, effective dates will be associated with the regional pot closure period.

NCDMF will mark boundaries of any proclaimed DTMAs and post informational signs similar to those marking other existing management areas. Posted signs will indicate all crab pots fished within the marked area will require the use of an approved terrapin excluder device from March 1 through October 31. A final version of the issue paper with NCMFC action will become a revision to the most recent Blue Crab Fishery Management Plan Amendment, named under the convention of: Revision year DTMA name(s). Revisions are then posted to the division web page.

Step 8 Summary:
If adopted by the NCMFC, the division will issue a proclamation and mark the boundaries of the DTMA at least one month prior to its effective date. The final issue paper will become a revision to the most recent Blue Crab Fishery Management Plan Amendment.

DTMA Summary

The framework adopted in this Amendment 3 was the next step necessary in implementing the NCMFC selected management strategy initially adopted in the 2013 Blue Crab FMP Amendment 2. Amendment 2 granted proclamation authority for the director of the NCDMF to require the use of terrapin excluder devices in crab pots. This framework defines the proclamation use criteria, and creates a stepwise process involving public comment, Advisory Committee consultation, and the most current scientific data, to develop Diamondback Terrapin Management Areas.

The framework is this document in total and consists of the following criteria:

- Step 1 Determine NCDMF approved terrapin excluder device types and sizes to be required
- Step 2 Determine dates when terrapin excluder devices will be required
- Step 3 Identify the zone of potential diamondback terrapin interaction with crab pots
- Step 4 Validate diamondback terrapin presence and overlap with zone of potential crab pot interaction
- Step 5 Determine appropriate Diamondback Terrapin Management Area boundaries
- Step 6 Initial issue paper detailing the proposed DTMA will be presented to the appropriate regional committee and receive public comment
- Step 7 NCMFC review documents and take action to adopt, adopt with modification, or deny proposed DTMA
- Step 8 Implement adopted DTMA by proclamation and incorporate the finalized issue paper as a revision to the FMP

The targeted DTMA approach offers improved localized protection of diamondback terrapins and minimizes the impacts to the statewide crab fishery (commercial and recreational). As crabbers typically fish their pots within one specific region, terrapin excluder device requirements for DTMAs will disproportionally affect those fishermen who set pots within the DTMA. While this may be viewed as unfair to these impacted fishermen, these areas will be determined using the best available data to have significant overlap with diamondback terrapins and the highest probability of diamondback terrapin interactions occurring with crab pots. A broader seasonal application of a less restrictive 5 x 16 cm (2 x 6.3 in.) terrapin excluder device across all pots fished in less than 3 m (9.8 ft.) of water and less than 250 m (820.2 ft.) from shore, may be viewed as more equitable. However, using pot set depth or distance from shore as criteria for requiring terrapin excluder devices is not realistically enforceable, and the use of less restrictive terrapin excluder devices may not be effective at preventing size selective mortality and localized extirpations. Broader regional requirements for the use of terrapin excluder devices would result in a greater reduction of diamondback terrapin bycatch overall but would also have a significant impact on blue crab commercial harvest and place an undue restriction on crab pots fished too deep or far from shore to incidentally capture diamondback terrapins.

The goal of this management strategy is to reduce diamondback terrapin capture and mortality in crab pots. Areas designated as DTMAs will minimize the inclusion of areas too deep or far from shore and help prevent the capture of diamondback terrapins in crab pots during the active season. However, not all areas within the zone of potential interaction will be designated as DTMAs. Smaller management areas within the overall zone of potential interaction will be created to protect specific areas documented to contain populations of diamondback terrapins and focus on including areas such as reserves or refuges designated as environmentally sensitive or important habitats for the protection of wildlife. This targeted DTMA approach is the most focused way to offer diamondback terrapin populations the greatest protection from bycatch mortality while having the least overall impact to the statewide blue crab fishery. Proactively taking these steps to address diamondback terrapin bycatch in crab pots may help mitigate the need to seek further state or federal protection (Threatened or Endangered listing) of diamondback terrapins. Additionally, addressing this issue may help improve future ratings the blue crab pot fishery receives from groups like Seafood Watch and the ability for the fishery to achieve sustainable harvest certifications from groups like the Marine Stewardship Council.

Initially, given the existing rule language, the division was not seeking NCMFC approval as an action under the framework prior to the issuance of a DTMA proclamation. The rationale was based on if the NCMFC did not agree with a particular DTMA established through this process, G.S. 113-221.1 allows the NCMFC to call an emergency meeting, at the request of five or more members, to review a proclamation issued under the authority delegated to the Fisheries Director. At that meeting the NCMFC may approve, cancel, or modify the proclamation. During the adoption of Amendment 3, the NCFMC formally added a step to bring proposed management areas back to the NCMFC at the next regularly scheduled NCMFC meeting following required regional advisory committee meetings for approval.

VI. PROPOSED RULE(S)

No rule change required. Proclamation authority is contained in existing rule (NCMFC Rule 15A NCAC 03L .0204(b)).

VII. RECOMMENDATIONS

NCMFC Selected Management Strategy
Adopted the framework and criteria presented by the NCDMF for identifying diamondback terrapin management areas, adding a step to bring proposed management areas back to the NCMFC following committee meetings at the next regularly scheduled meeting for approval.

NCMFC Summary
At their November 2019 business meeting, the NCMFC preferred management strategy for DTMAs was the use of science on locally specific pot funnel design to reduce terrapin interactions and identify individual areas with terrapin population hot spots that would be closed to potting unless an excluder is used.

At the February 2020 business meeting, the division asked for clarification of the preferred management strategy over concerns of limited criteria details and enforcement capabilities. The NCMFC changed their final management strategy to adopt the framework and criteria for designating DTMAs where use of an approved terrapin excluder device will be required. The NCMFC also added a step to the framework to bring proposed management areas back to the NCMFC following committee meetings at the next regularly scheduled meeting for approval

This eight-step framework covers criteria for approved terrapin excluder devices, time period when excluders are required in pots, terrapin interaction zone, terrapin presence, boundary designation, issue paper development with AC recommendations and public comment, NCMFC action, and implementation by proclamation.

The final issue paper for each NCMFC approved DTMA(s) will become a revision to the current FMP Amendment. See Attachment 1 for an **EXAMPLE** of an issue paper. These Amendment revisions may be made to approve additional terrapin excluder devices, amend DTMA boundaries, and create new DTMAs. Revision documents may be viewed on the DMF website.

See Appendix 4.7 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Blue Crab FMP Amendment 3.

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ATTACHMENT 1: EXAMPLE OF A POSSIBLE ISSUE PAPER ON PROPOSED DIAMONDBACK TERRAPIN MANAGEMENT AREAS USING MASONBORO SOUND AND THE LOWER CAPE FEAR RIVER [**illustrative purpose and may differ from actual issue paper, see Revision(s) for approved DTMA(s)**]

Diamondback terrapins are listed by the North Carolina Wildlife Resources Commission (NCWRC) as a North Carolina species of "Special Concern" statewide and as a Federal "Species of Concern" in Dare, Pamlico and Carteret counties in NC. Numerous studies have concluded that incidental bycatch in crab pots is the most serious threat to diamondback terrapins in North Carolina and throughout their range (1). Diamondback terrapins are susceptible to substantial population declines or even localized extirpations through incidental bycatch in crab pots and removal of a relatively low number of individuals from the population annually (2).

Diamondback Terrapin Management Areas (DTMAs) are discrete areas within the estuarine and coastal waters of North Carolina which have been designated by the North Carolina Division of Marine Fisheries (NCDMF) to reduce bycatch of diamondback terrapins in the blue crab pot fishery though the use of terrapin excluder devices. These areas have been documented to contain populations of diamondback terrapins through capture in NCDMF sampling programs, and/or through academic research, as well as contain significant waterbody area in which diamondback terrapins are susceptible to incidental capture in crab pots (water less than 3 m (9.8 ft.) deep as well as less than 250 m (820.2 ft.) from shore). The criteria and framework which identifies and creates a DTMA is described and established in the issue paper: Establish a Framework to Implement the Use of Terrapin Excluder Devices in Crab Pots, in Amendment 3 of the Blue Crab Fishery Management Plan. In an area designated as a DTMA, all crab pots (including peeler pots) fished between February 28 and October 31 are required to have approved terrapin excluder devices and constructed out of heavy plastic or wire no smaller than 10-gauge) properly secured in each funnel opening. Excluder devices would not be required to be used if the maximum inner opening dimensions of all funnel entrances did not exceed those of an approved excluder device.

The areas behind Masonboro Island and in the lower Cape Fear River behind Bald Head Island have been identified as containing populations of diamondback terrapins using NCDMF and North Carolina Natural Heritage Program (NCNHP) data sets, as well as being a potential area for diamondback terrapin interactions with crab pots (Figure A1). Both areas have also served as study sites for academic diamondback terrapin research on abundance as well as documenting and verifying interactions and bycatch in crab pots (3; 4; 5; 6; 7; 8; 9; 10; 11).

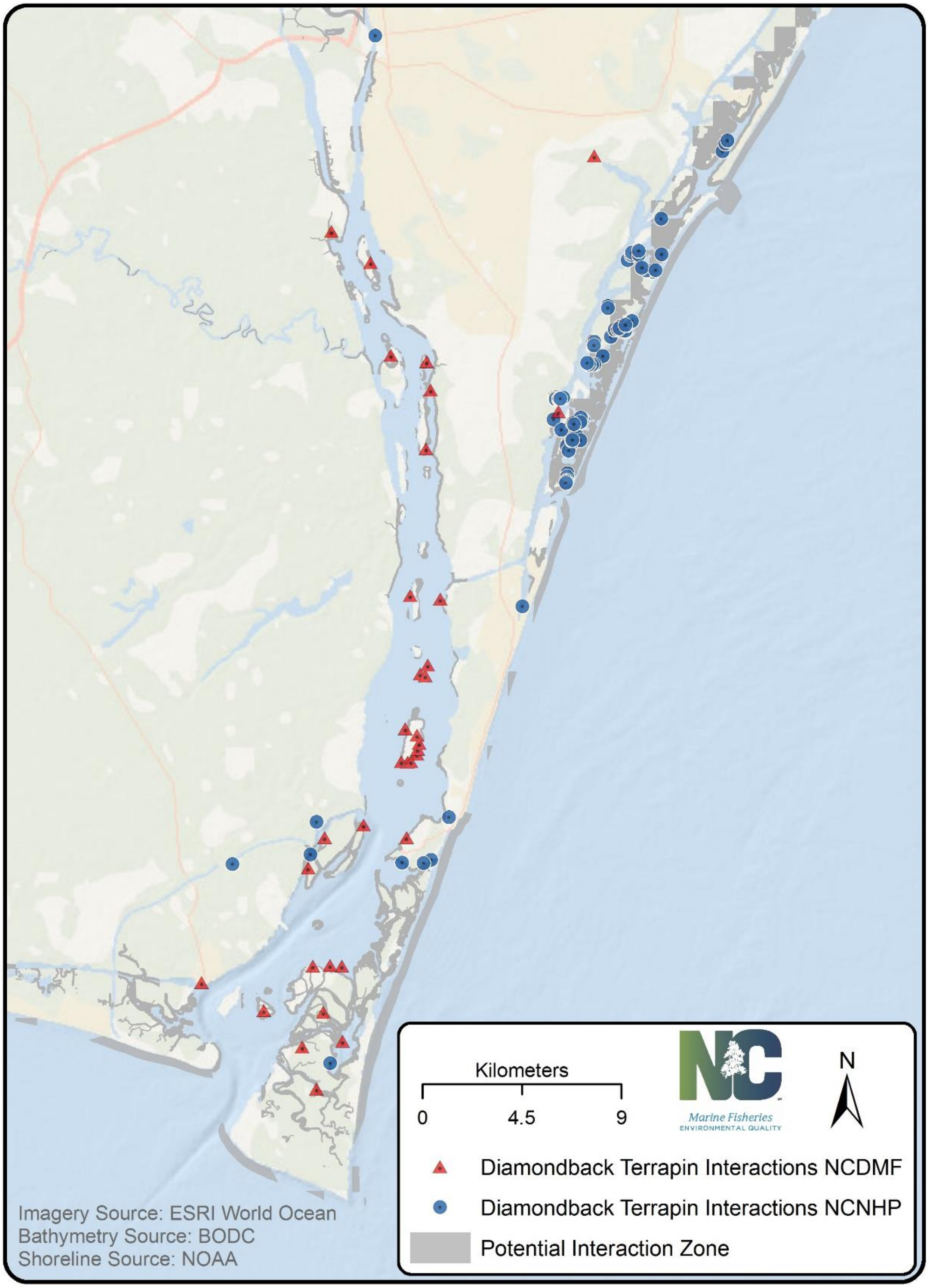

Figure A1. A map of coastal New Hanover and Brunswick counties showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

Summary of Diamondback Terrapin Research Documenting Presence and Interaction with Crab Pots

Grant (3) identified the marshes behind Masonboro Island as an area with both a population of diamondback terrapins and an active commercial blue crab pot fishery. Diamondback terrapins were documented and captured in crab pots. Terrapin excluder devices were tested and opening heights of 4 cm (1.6 in.) resulted in 100% exclusion of diamondback terrapins compared to 5 cm (2 in.) height terrapin excluder devices which still allowed diamondback terrapin capture in crab pots. Both terrapin excluder device dimensions resulted in reductions in blue crab catch.

Thorpe et al. (4) captured terrapins in crab pots fished in a typical manner by a commercial fisherman set in a location in the lower Cape Fear River near Bald Head Island, NC during a crab pot bycatch study. It was commented that the rate of diamondback terrapin capture suggests a high potential for bycatch.

Thorpe and Likos (5) evaluated terrapin excluder devices in commercial blue crab pots in the lower Cape Fear River near Bald Head Island, NC. One diamondback terrapin was captured in a crab pot using a 5 x 12 cm (2 x 4.7 inches) excluder, and recommended further assessment based on terrapin size and range in NC. Additionally, recreational and recreational commercial gear license crab pots were observed tied to piers and set close to shore in creeks in areas which would likely have diamondback terrapins.

Southwood et al. (6) used radio telemetry to document diamondback terrapin distribution and habitat use in the lower Cape Fear River and near Masonboro Island. Diamondback terrapins were documented in these areas, and when found swimming they were typically in shallow water less than 3 m (9.8 ft.). Both alive and dead diamondback terrapins were observed entrapped in a crab pot which was exposed during low tide. It was suggested that placing crab pots in deeper water and further from the marsh edge would help reduce diamondback terrapin bycatch.

Alford (7) used tall crab pots (which prevented bycatch mortality) to capture diamondback terrapins and monitor their population between May and October in the areas behind Masonboro Island. Diamondback terrapins were captured at the highest frequency in May, and 65% of all captured diamondback terrapins were male. As males were more likely to be captured in crab pots it was suggested there was the potential to cause a skewed sex ratio due to bycatch mortality.

Southwood Williard and Harden (8) used a postcard survey to investigate potential interactions between blue crab fisheries and diamondback terrapins. Results of this survey were incorporated into the NCNHP dataset, which include occurrences near Bald Head Island and behind Masonboro Island.

Harden and Southwood Williard (9) evaluated the seasonal bycatch risk of diamondback terrapins in crab pots. Diamondback terrapins were captured and monitored by radio telemetry behind Masonboro and Figure Eight Islands, New Hanover Co., NC. Diamondback terrapins were observed to be active and out of dormancy between April 1 and September 30. Crab pots were documented in these areas during the diamondback terrapin active season and were found to typically be located between 15 and 30 m (49 and 98 ft.) from the marsh edge and in water ranging from 0 to 2.8 m (0 to 9.8 ft.) deep at low tide. Between June 2008 and May 2009, four of the 29 monitored diamondback terrapins were captured as bycatch in crab pots. Results indicate crab pots and diamondback terrapins co-occur with a patchy distribution, resulting in a greater than expected potential for interaction than if both were uniformly distributed.

Chavez and Southwood Williard (10) assessed the impact of two terrapin excluder device sizes, 5.1 x 15.2 cm, and 3.8 x 15.2 cm (2 x 6 in. and 1.5 x 6 in.), in crab pots on blue crab catch at sites in Masonboro and Bogue sounds, NC. Areas behind Masonboro Island had the highest rates of capture in crab pots. It was concluded the larger size terrapin excluder device allowed male diamondback terrapins to enter traps, while the smaller size would have prevented their capture. Nether terrapin excluder device has a statistically significant impact on blue crab size or catch. However, the smaller excluder did show a non-significant downward trend.

Munden (11) examined the population change of diamondback terrapins around Masonboro Island between 2009 and 2017, along with the number of crab pots. Diamondback terrapin head count and crab pot survey data collected as part of a fixed kayak route citizen science project during this period was analyzed. Mean number of diamondback terrapins observed per kilometer in 2017 decreased to a low of 0.016 from a high of 0.938 in 2014, while the mean number of crab pots observed per kilometer in increased to 2.435 in 2107 from 0.804 in 2014.

Existing Ecological Areas

Both Masonboro Island and the region in the lower Cape Fear River north of Bald Head Island are comprised of lands designated as North Carolina Natural Heritage Natural Areas (hereinafter referred to as Natural Areas) as well as designated National Estuarine Research Reserves (NERRs; Figure A2). Natural Areas are designated by the North Carolina Division of Parks and Recreation to protect areas sensitive to human activities and preserve and protect areas of scientific, aesthetic, or ecological value. The NERR system is a network of protected areas across the United States which protects costal and estuarine habitats for long-term research, education, and coastal conservation. The overarching goal of the national NERR system is to provide a foundation for effective coastal management through site research. Masonboro Island Reserve contains the largest undisturbed barrier island in the southern part of the North Carolina coast, and is considered an intact barrier island and estuarine ecosystem. Zeke's Island Reserve contains a complex of salt marshes, tidal flats, and barrier islands.

The site manager for both reserve locations has expressed concern for declining diamondback terrapin head count numbers coinciding with increased crab pot numbers observed in the annual citizen science fixed route kayak survey and has provided example results (Figures A3-A5). Negative impacts from crab pot mortality and low rates of recolonization may prevent maintaining existing populations of diamondback terrapins in refuges or reserves unless their loss through bycatch is minimized (12). The areas encompassing both Masonboro Island and the lower Cape Fear River north of Bald Head Island have also been nominated as Strategic Habitat Areas (SHAs) by the NCMFC (Figure A6). SHAs represent priority locations for protection or restoration due to their exceptional ecological functions or areas particularly at-risk due to imminent threats to their ability to support coastal fisheries. The large areas in Masonboro Sound and the Cape Fear River were selected due to their biodiversity and high quality of habitats and fishery species. These SHAs also overlap with lands already managed for conservation, and were corroborated with biological data, ecological designations, and specific knowledge of the area.

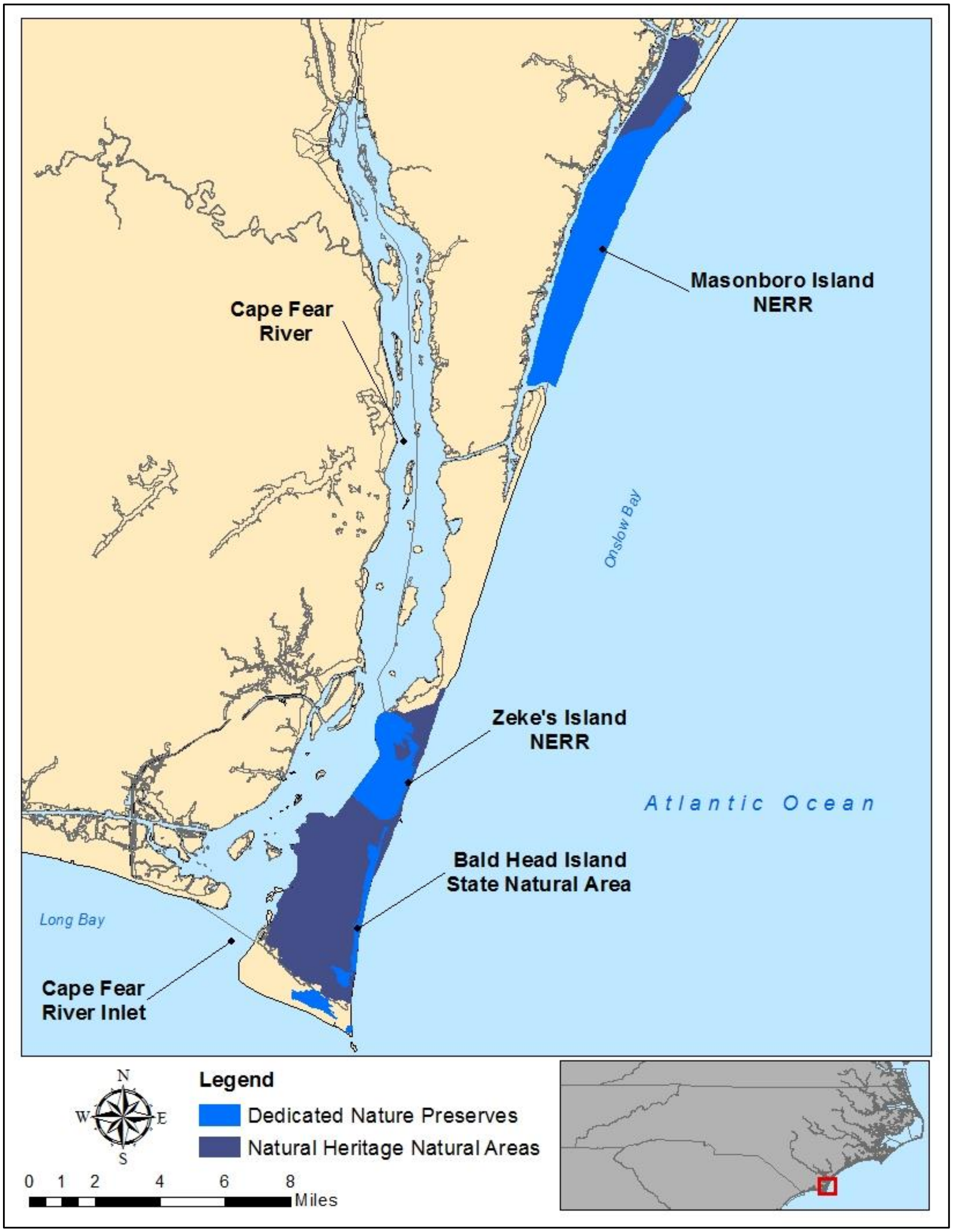

Figure A2. A map of coastal New Hanover and Brunswick counties showing North Carolina Natural Heritage Natural Areas and National Estuarine Research Reserves (NERRs)

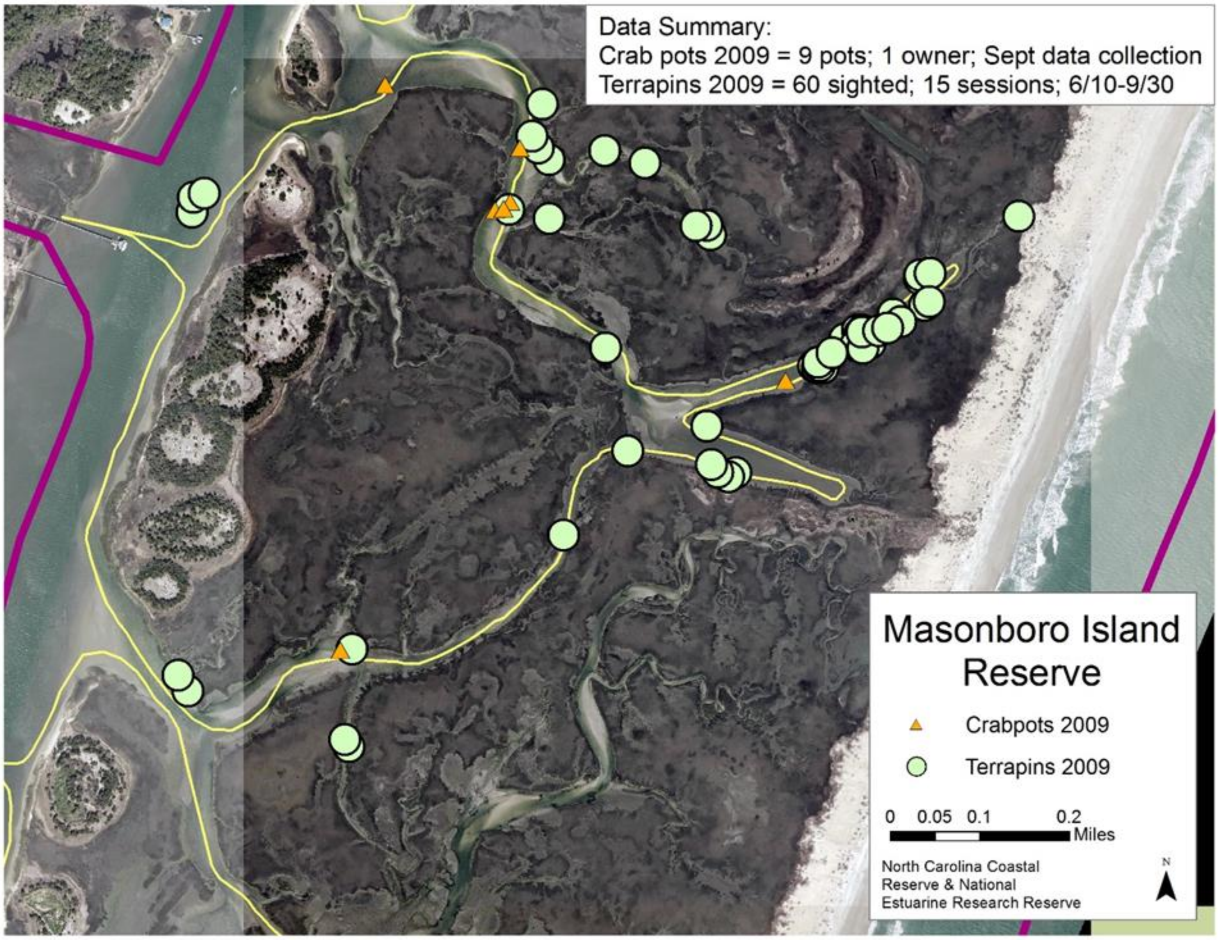

Figure A3. A map showing diamondback terrapin and crab pot locations and counts from a fixed route kayak survey conducted in the Masonboro Island NERR in 2009. Example results of diamondback terrapin and crab pot count data from fixed route kayak surveys in Masonboro Island National Estuarine Research Reserve.

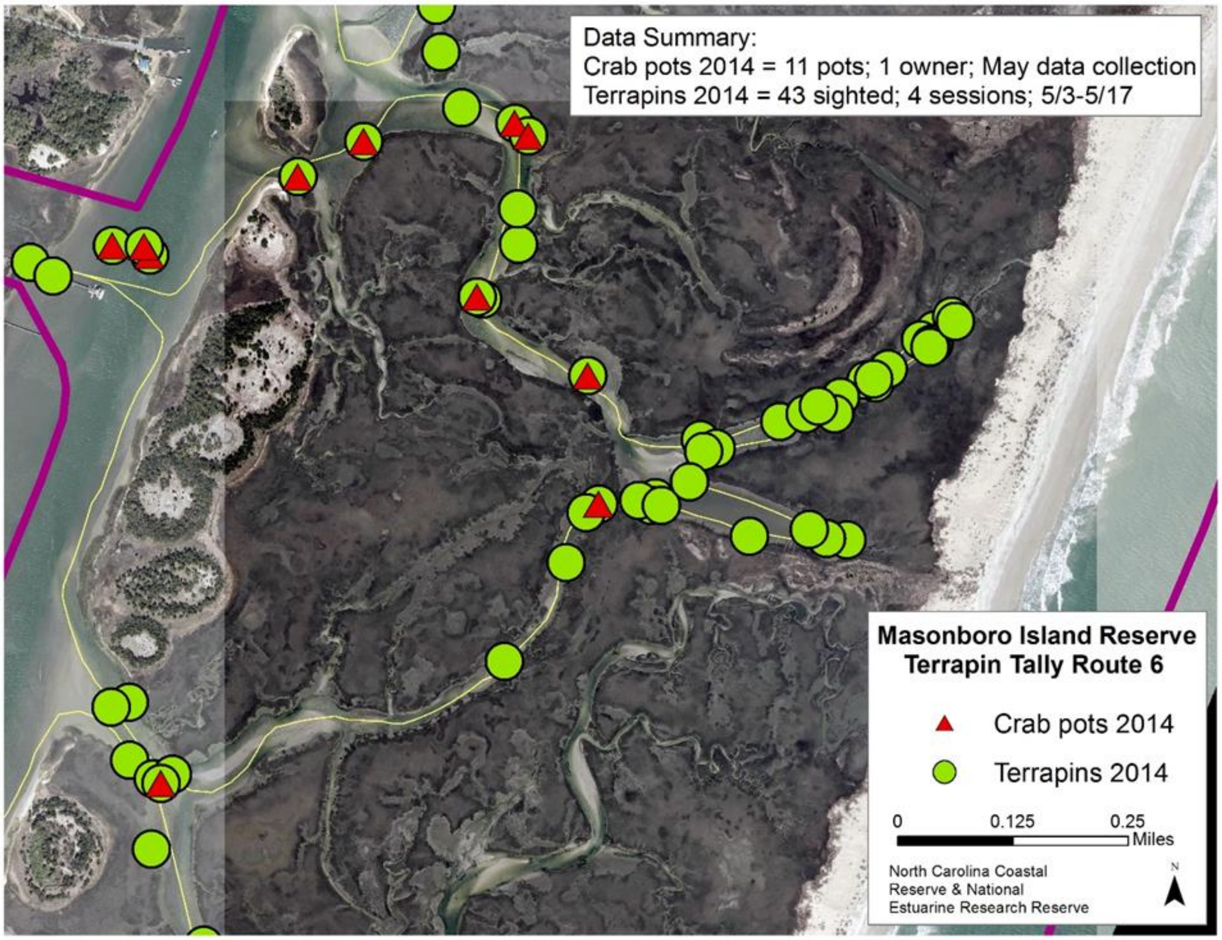

Figure A4. A map showing diamondback terrapin and crab pot locations and counts from a fixed route kayak survey conducted in the Masonboro Island NERR in 2014. Example results of diamondback terrapin and crab pot count data from fixed route kayak surveys in Masonboro Island National Estuarine Research Reserve.

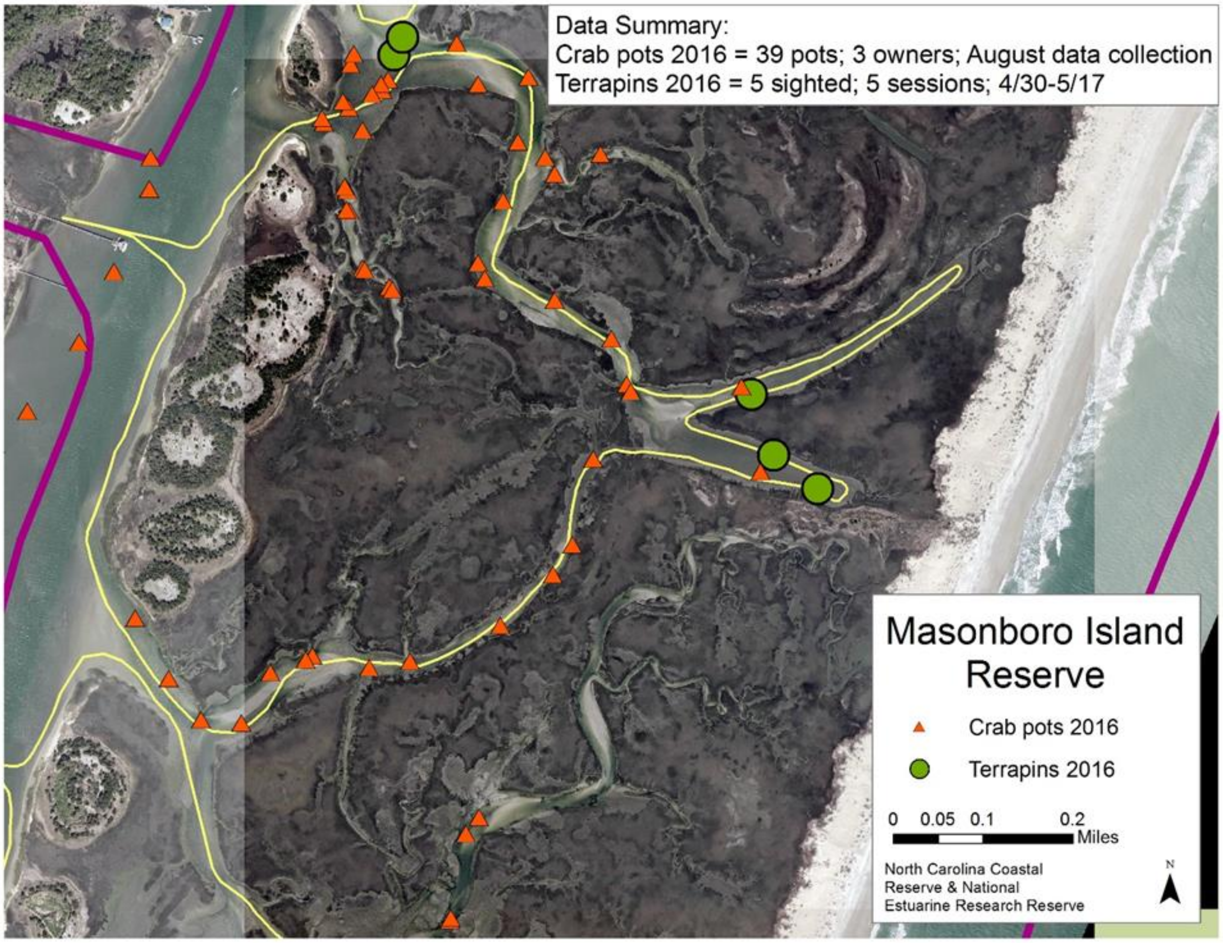

Figure A5. A map showing diamondback terrapin and crab pot locations and counts from a fixed route kayak survey conducted in the Masonboro Island NERR in 2016. Example results of diamondback terrapin and crab pot count data from fixed route kayak surveys in Masonboro Island National Estuarine Research Reserve.

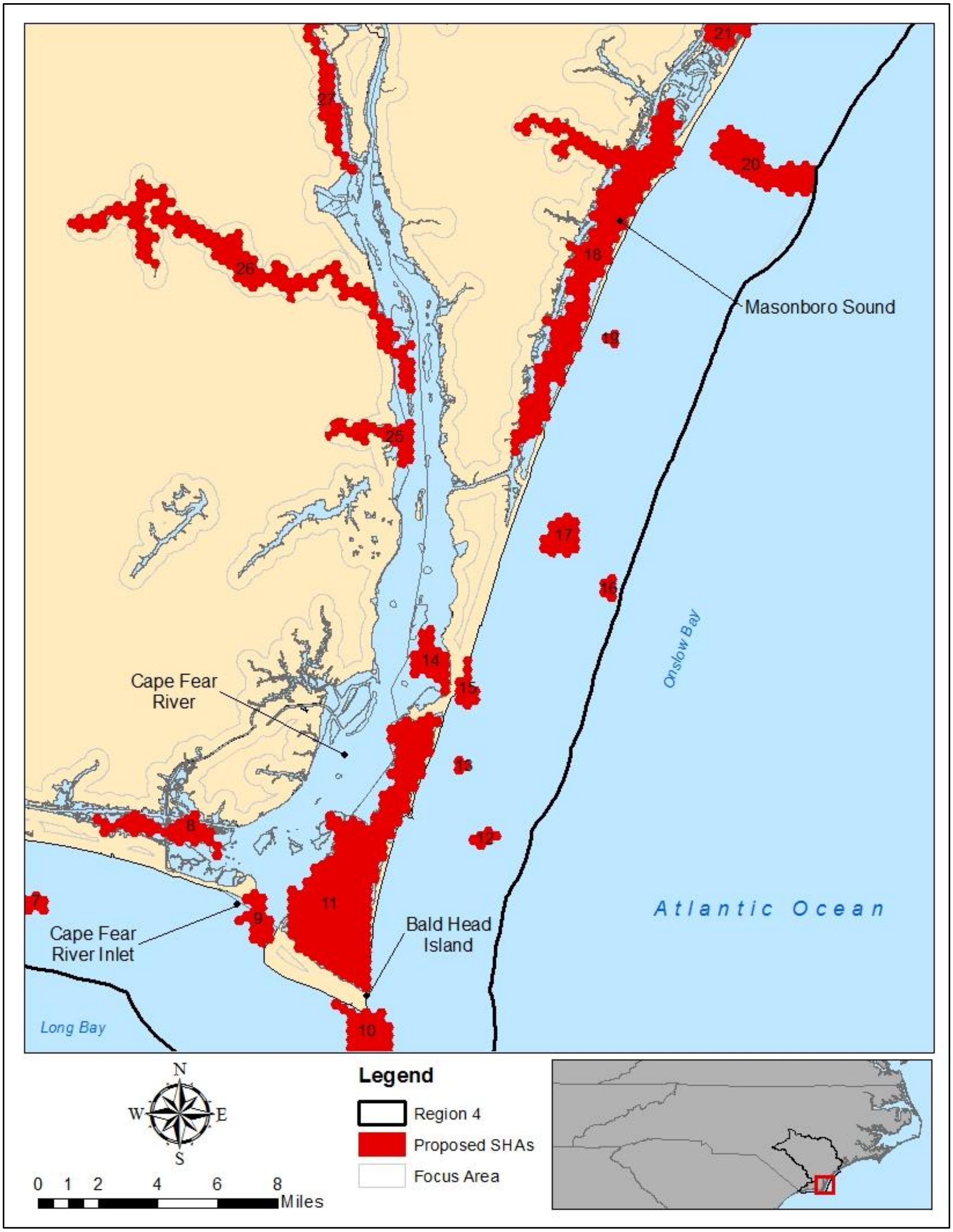

Figure A6. A map of coastal New Hanover and Brunswick counties showing nominated Strategic Habitat Areas in Region 4 of the North Carolina Coastal Habitat Protection Plan.

Proposed Management Areas

Two Diamondback Terrapin Management Areas (DTMAs) are proposed, the Masonboro Island DTMA and the Bald Head Island DTMA (Figure A7). The proposed Masonboro Island DTMA lies entirely within, and shares nearly the entire boundary with, the Masonboro Island Estuarine Research Reserve and Natural Area. This area is also naturally bounded on the east by Masonboro Island, and on the west by the Intracoastal Waterway (IWW). The proposed Bald Head Island DTMA is comprised of Zeke's Island Estuarine Research Reserve in the northern portion of the management area and the Bald Head Island State Natural Area as the southern portion. This area is also naturally bounded by a barrier island to the east, and Bald Head island to the south. The western boundary of this management area follows the "Wall", a rock structure that separates the Cape Fear River from Buzzard Bay, and also serves as the boundary for the Zeke's Island Estuarine Research Reserve. At the end of the wall, a line is drawn southwesterly to the northern tip of Bald Head Island. These two areas use boundaries such as the IWW, landmarks, or existing reserve borders to maximize ease of marking these areas and enforcement.

Each DTMA has been selected to minimize the inclusion of areas outside the zone of potential diamondback terrapin interaction with crab pots, without creating overly complex and unenforceable borders (Table A1). Of the area that is water in the Masonboro Island DTMA, 85% meets the depth and distance criteria considered within the interaction zone, and 61% of the water area in the Bald Head Island DTMA is considered within the interaction zone. The area in the Masonboro Island DTMA that does not fall within this zone is primarily in Dick Bay, which is mostly less than 3 m (9.9 ft.) deep at low tide, but is a large open area which contains area greater than 250 m (820.2 ft.) from any shoreline. Dick Bay is included within the proposed DTMA to reduce complexity in marking and enforcement, as the IWW forms a natural western boundary for this management area. In the Bald Head Island DTMA, the amount of water area that is not considered in the interaction zone is primarily caused by the larger open areas of water to the east of the Wall in the Basin, Second Bay, and Buzzard Bay. These areas are mostly less than 3 m (9.8 ft.) deep at low tide but have area that is greater than 250 m (820.2 Ft.) from any shoreline. These areas were also included in the proposed DTMA to reduce complexity in marking and enforcement, as the Wall forms a well-defined boundary for this management area.

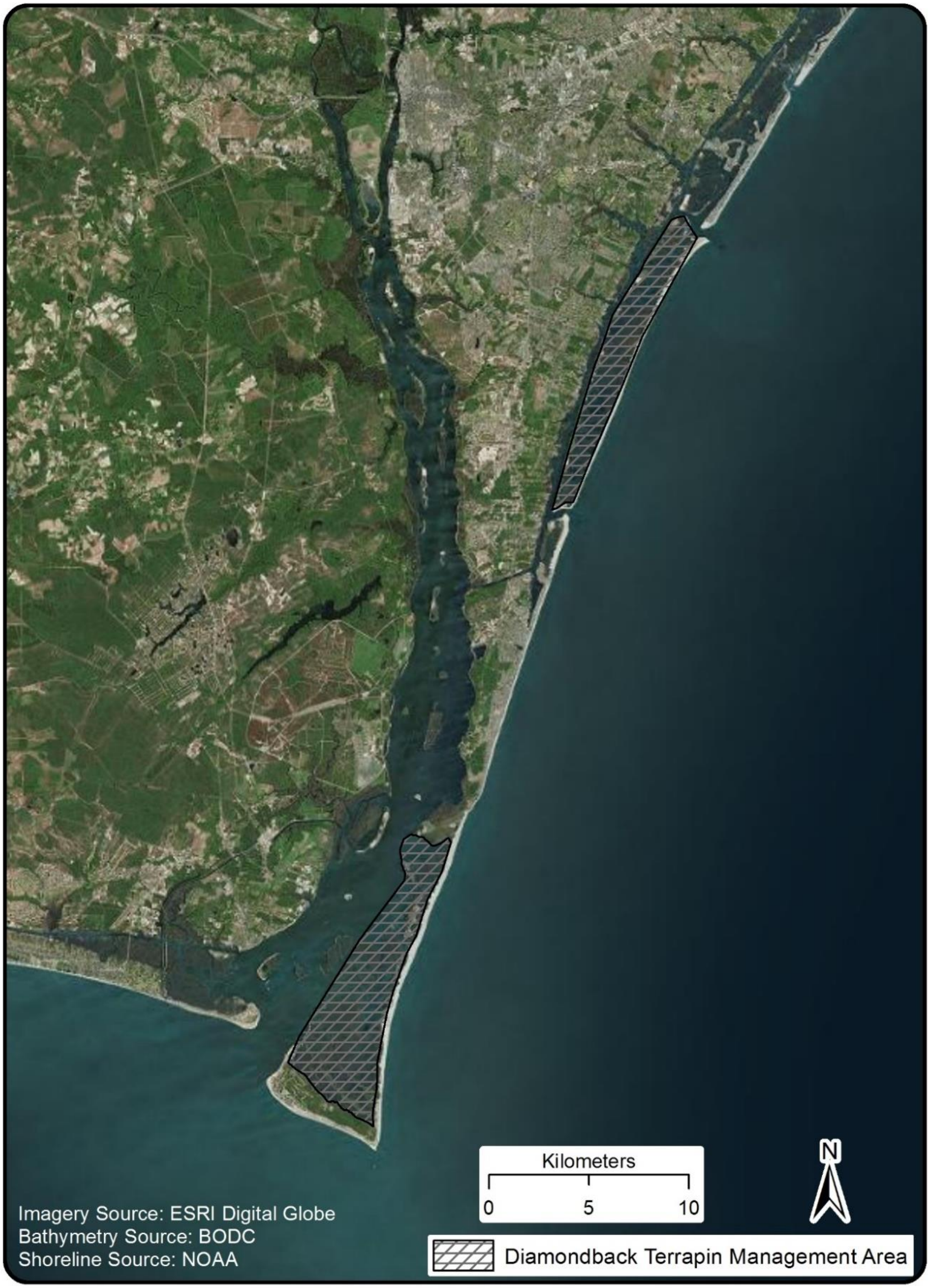

Figure A7. A map of coastal New Hanover and Brunswick counties showing proposed Diamondback Terrapin Management Areas.

Table A1. Total area in acres of proposed Masonboro and Bald Head Island DTMAs, including percent of DTMA that is water, percent of water area that is in the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.)), and percent of the total Trip Ticket reporting area (Masonboro Sound, Cape Fear River) the DTMA encompasses.

Acreage Category	Masonboro	Bald Head
Total land and water area of DTMA (acres)	5,739	9,945
Percent of DTMA area that is water	59%	39%
Percent of DTMA water area in interaction zone	85%	61%
Percent DTMA is of total Trip Ticket reporting area	64%	29%

Regional Commercial Blue Crab Fishery Information

Landings and participation data for the blue crab fishery does not exist at a fine enough scale relative to specific waterbodies to directly assess the number of participants which could be impacted by the creation of the proposed DTMAs. Trip ticket reporting areas for this region include Masonboro Sound, which encompasses the proposed Masonboro Island DTMA and the Cape Fear River, which encompasses the proposed Bald Head Island DTMA. The proposed Masonboro Island DTMA comprises 64% of the Masonboro Sound trip ticket reporting area, while the proposed Bald Head Island DTMA comprises 29% of the Cape Fear River trip ticket reporting area (Table A1). From 2007 and 2016, between 12 and 19 (average of 15) participants reported landings of blue crabs from hard crab and peeler pots from Masonboro Sound, and between 9 and 22 (average 15) participants reported landings of blue crabs from hard crab and peeler pots from the Cape Fear River (Figure A8). Participants reporting landings are generally declining in the Cape Fear River and increasing in Masonboro Sound. Although the proposed Masonboro Island DTMA occupies a smaller footprint, it may likely impact more individual participants than the proposed Bald Head Island DTMA as there are more participants and the proposed Masonboro Island DTMA occupies a greater percentage of the trip ticket reporting area.

Additional species which are landed from crab pots in these two trip ticket reporting areas include whelks “conch” (*Busycon and Busycotypus spp*.), and Florida stone crabs (*Menippe mercenaria*). Landings and participation data for whelk examined by trip ticket reporting area are considered confidential (having a small number of participants) when examined on an annual scale and are presented as ten-year averages (Table A2). From 2007 and 2016, between 4 and 10 (average of 7) participants reported landings of stone crab from hard crab and peeler pots from Masonboro Sound, and between 3 and 8 (average 5 participants reported landings of stone crab from hard crab and peeler pots from the Cape Fear River (Figure A9). Landings of stone crabs show fluctuations in number between years and area and average a very small percentage (less than .5%) of the overall landings from crab pots in these two reporting areas. Ten-year average (from 2007 to 2016) landings values for these three species from the Masonboro Sound and Cape Fear River trip ticket reporting areas show Blue Crab as the highest average landings values, followed by stone crab then whelk (Table A3).

Table A2. Average landings of whelk (conch) meats from hard crab and peeler pots, and average number of participants reporting landings between 2007 and 2016 from Trip Ticket reporting areas Masonboro Sound, and Cape Fear River.

Trip Ticket Area	Average Landings	Average Number of Participants
Masonboro Sound	43	2
Cape Fear River	76	3

Table A3. Average value of reported landings of blue crab, whelk (conch), and stone crab from hard crab and peeler pots, between 2007 and 2016 from Trip Ticket reporting areas Masonboro Sound, Cape Fear River, and statewide total. Numbers in parenthesis represent the percentage of each area to the statewide average for each species.

Species	Masonboro Sound	Cape Fear River	Statewide
Blue Crab	$ 116,809 (0.46%)	$ 580,185 (2.32%)	$24,954,534
Whelk	$ 87 (0.11%)	$ 150 (0.19%)	$80,890
Stone Crab	$ 1,407 (7.52%)	$ 970 (5.18%)	$18,717

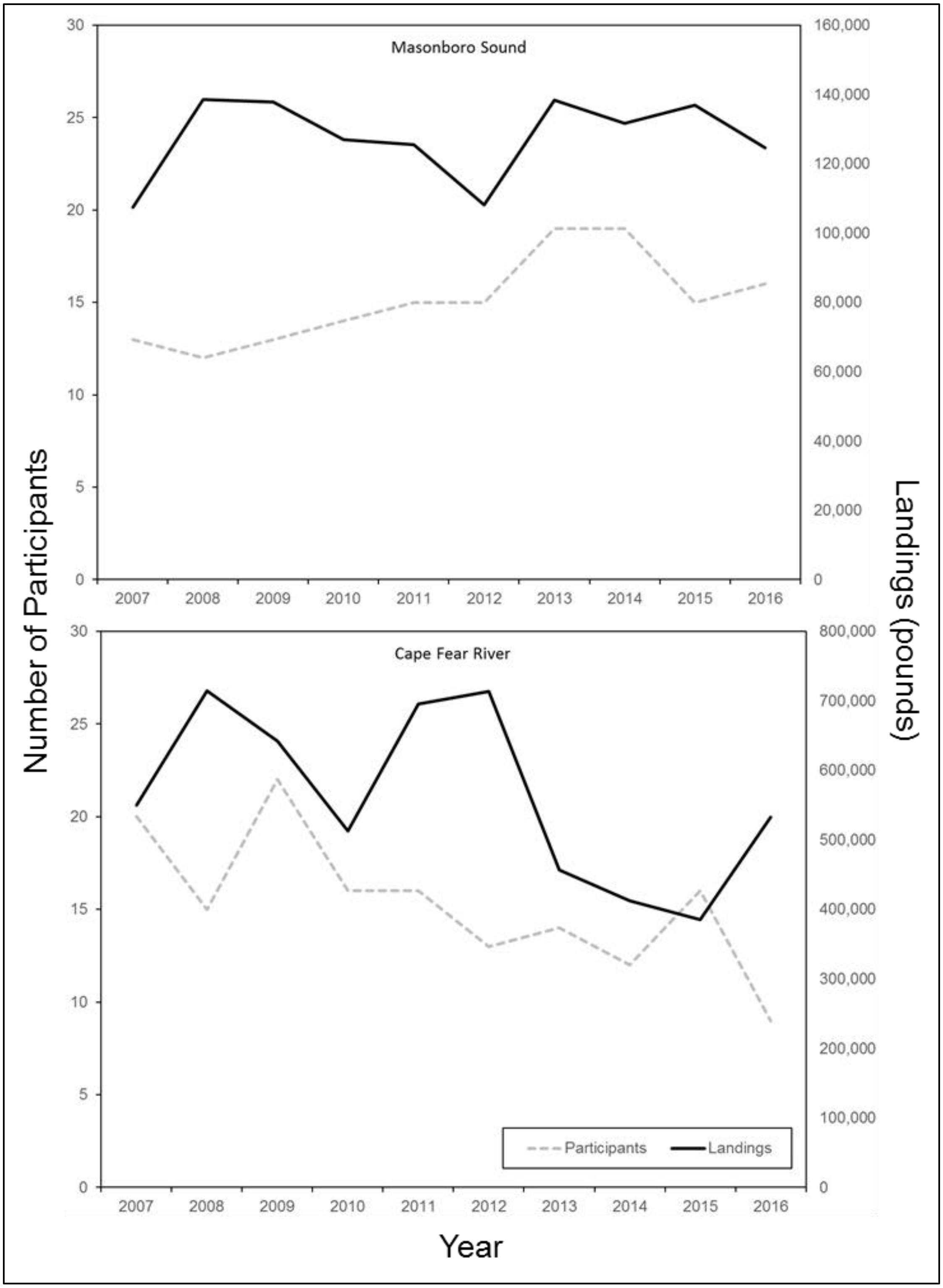

Figure A8. A graph showing number of participants (left axis, dashed line) and landings in pounds (right axis, solid line) of blue crabs in both, hard crab and peeler pots for the Masonboro Sound (upper panel) and Cape Fear River (lower panel) trip ticket reporting areas.

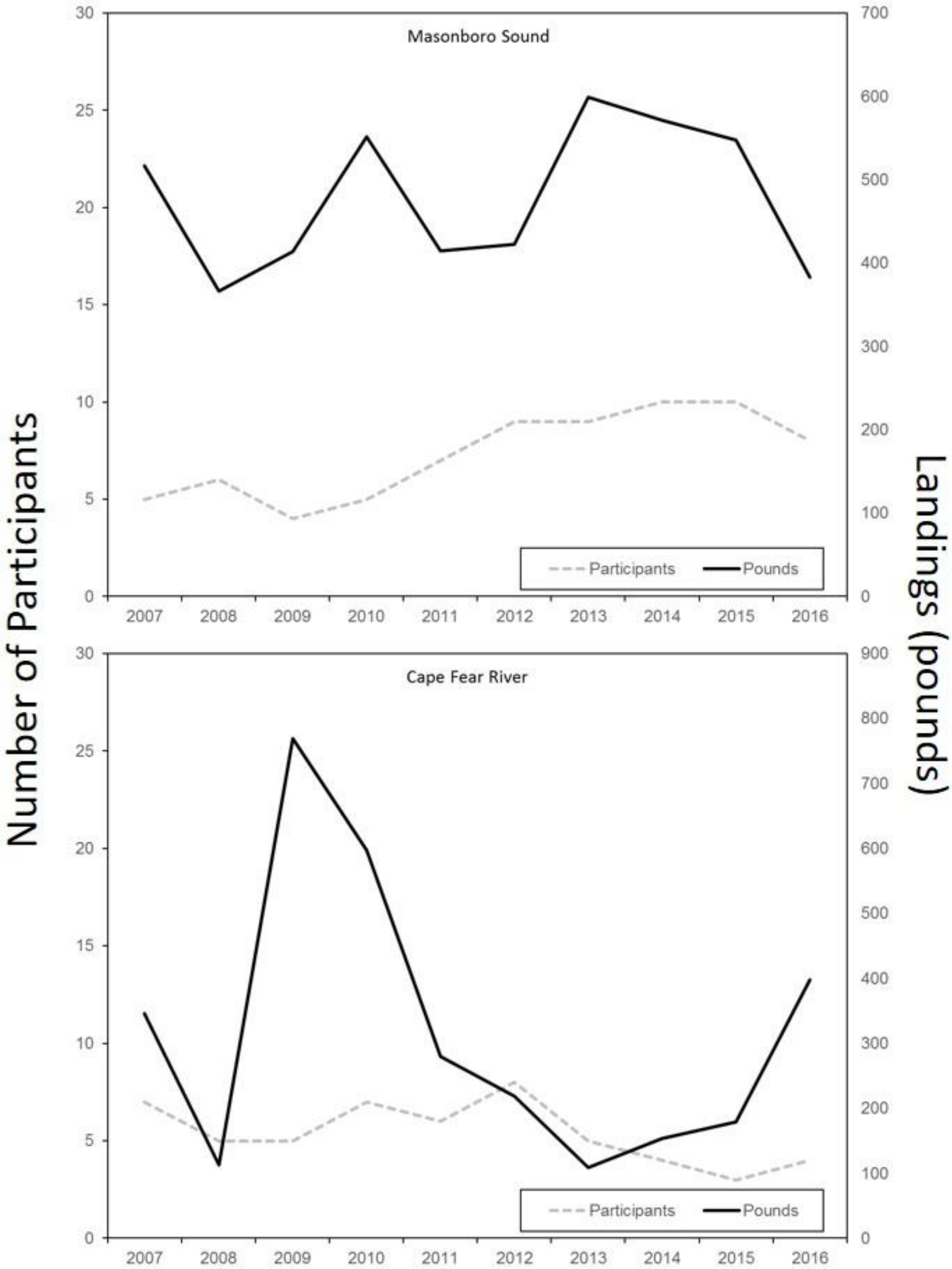

Figure A9. A graph showing number of participants (left axis, dashed line) and landings in pounds (right axis, solid line) of stone crabs in both, hard crab and peeler pots for the Masonboro Sound (upper panel) and Cape Fear River (lower panel) trip ticket reporting areas.

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APPENDIX 4.6: BOTTOM DISTURBING GEAR IN THE BLUE CRAB FISHERY

I. ISSUE

Limit the use of bottom disturbing fishing gear in the blue crab fishery (dredges and trawls), to reduce habitat impacts and improve spawning potential by mature females.

II. ORIGINATION

The "Fishery Impacts to the Ecosystem" section of this plan described habitat impacts associated with dredging and trawling. The NC Coastal Habitat Protection Plan requires that habitat is protected from adverse fishing gear effects. This issue paper will evaluate the need for regulatory changes associated with crab dredging and crab trawling.

III. BACKGROUND

The crab trawl and dredge fisheries have important historical and cultural significance to North Carolina's commercial fishing past. Since the turn of the twentieth century, and the advent of the motorboat, these gears have provided a way for fishermen to harvest crabs in the winter when other gears are ineffective. Due to market demands and the predominance of crab pots for the better part of the last century, crab trawl and dredge landings have waned, making up less than one percent of all crab landings in 2017. Despite their historical significance, these gears present both fishery and habitat level concerns. As discussed in the issue paper "Management Options Beyond Quantifiable", these fisheries predominately catch mature female crabs in some areas that are bedded down in the mud, overwintering. Crab trawl and dredge fisheries utilize bottom disturbing gear that can damage fragile habitats critical to a wide variety of North Carolina's important fish and invertebrate species.

The targeting of blue crabs with dredges on public bottom is restricted to one designated area in northern Pamlico Sound, during certain times of year when open (NCMFC Rule 15A NCAC 03L .0203 (a)(1)); or when taken as incidental catch during lawful oyster dredging (NCMFC Rule 15A NCAC 03L .0203 (a)(2)). The taking of blue crabs with crab trawls on public bottom is permitted in large areas of coastal and joint waters south of the Albemarle Sound. Areas and times in which crab trawls may be used to harvest crabs is specified by proclamation (NCMFC Rule 15A NCAC 03L .0202).

In 2013, as part of the adaptive management framework approved in Amendment 2 to the Blue Crab Fishery Management Plan, NCMFC Rule 15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS was modified, adding:

15A NCAC 03L .0201
<u>(f) In order to comply with management measures adopted in the N.C. Blue Crab Fishery Management Plan, the Fisheries Director may, by proclamation, close the harvest of blue crabs and take the following actions for commercial and recreational blue crab harvest:</u>
    <u>(1) specify areas;</u>

(2) specify seasons;
(3) specify time periods;
(4) specify means and methods;
(5) specify culling tolerance; and
(6) specify limits on harvest based on size, quantity, sex, reproductive stage, or peeler stage.

A similar statement allowing proclamation authority to restrict the use of dredges to take crabs was also added (NCMFC Rule 15A NCAC 03L .0203 (a)(3)). Additionally, to reduce the bycatch of juvenile flounder in crab trawls, NCMFC Rule 15A NCAC 03L .0202 was modified, increasing the crab trawl minimum mesh length to take hard crabs to four inches in designated areas.

In Amendment 2, blue crabs were not overfished, but there were concerns due to declining indicators (1). A habitat recommendation to consider prohibiting crab dredging was included based on severe habitat damage that can result from dredging. Additionally, gear closure was a potential management strategy included in the blue crab adaptive management framework.

In the 2016 revision to Amendment 2, the NCMFC adopted a partial gear closure implemented through Proclamation M-11-2016. The designated crab dredge area in northern Pamlico Sound was closed; however, incidental harvest of crabs during lawful oyster dredging continued to be allowed as outlined in NCMFC Rule 15A NCAC 03L. 0203(a)(2). Once Amendment 3 to the Blue Crab FMP goes into effect, adaptive management measures for Amendment 2 will be discontinued unless re-adopted in Amendment 3 (2).

In part because the 2018 stock assessment indicated blue crabs were overfished and overfishing was occurring (3), a dredge gear closure, trawl gear modification, and area restriction are being revisited. However, the primary reason for evaluating the use of these gears in the blue crab fishery concerns their habitat impacts. While not contributing substantially to the blue crab fishery, bottom disturbing gears can substantially degrade SAV, shell bottom, soft bottom, and water quality due to high sediment disturbance (2). Further limiting the use of these gears would pose minimal economic impact to fishermen and reduce habitat impacts and fishing mortality of primarily adult females in some areas.

IV. AUTHORITY

North Carolina General Statute
113-134 RULES
113-182 REGULATIONS OF FISHING AND FISHERIES
113-221.1 PROCLAMATIONS AND EMERGENCY REVIEW
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03J .0104 TRAWL NETS
15A NCAC 03L .0202 CRAB TRAWLING

15A NCAC 03L .0203 CRAB DREDGING
15A NCAC 03R .0109 TAKING CRABS WITH DREDGES
15A NCAC 03R .0110 CRAB SPAWNING SANCTUARIES

V. DISCUSSION

Taking crabs with dredges

The dredge fishery had minimal crab landings in recent years (Table 4.6.1), with most dredge landings coming from oyster dredges in January and February (Table 4.6.2). Since 1995, landings from crab dredging were less than 10,000 lb./year, with the exception of 2010 when 52,769 lb. were landed. Blue crab landings from oyster dredging were minimal (less than 1000 lb.) from 1995 to 2003. From 2004 to 2016, landings increased slightly, with the exception of a sharp increase in landings in 2010 and 2011 (Table 4.6.1, Figure 4.6.1). This increase is reflective of a high abundance of crabs in the crab dredge area during the open season due to cooler than normal temperatures and the ease of entering the oyster dredge fishery with a shellfish license that had been intended for hand harvest only. Beginning with the 2012-13 oyster season, management changes were made to the means and methods for Mechanical Harvest of oysters to encourage culled material be returned on a reef. Also, a statutory change in 2013 limited shellfish harvest using the shellfish license to hand harvest only. These changes, along with lower abundance of adult oysters in the Pamlico system, led to lower effort and crab landings after 2011.

The crab dredge fishery is only allowed by NCMFC rule in a designated crab dredge area in northern Pamlico Sound (Figure 4.6.2) in January and February. However, it has remained closed by proclamation since June 2016. The total designated dredge area is 86,899 acres. A Seed Oyster Management Area (SOMA) and three oyster sanctuaries (Crab Hole, Croatan, and Pea Island) occur within the crab dredge area. Dredging is not permitted within oyster sanctuary boundaries. The estuarine portion of the Oregon Inlet Crab Spawning Sanctuary is also within the designated crab dredge area (see Figure 4.4.4).

There are 8,071 acres of SAV and 308 acres of shell bottom mapped within the crab dredging area. Areas greater than 15-ft have not been mapped for shell bottom, therefore the total acreage of shell bottom is likely underestimated. These sensitive habitats are critical to various life stages of blue crabs along with numerous other fish and invertebrates. Because of the diversity of habitat in this area, the critical location as a migratory corridor to the ocean, and good quality of the habitats and water quality, and the ecosystem services provided by these habitats several Strategic Habitat Areas were designated within the dredge area as part of CHPP Regions 1 and 2. Ecosystem services provided by SAV and shell bottom include stabilizing sediment, improving water clarity, reducing shoreline erosion, and stabilizing marsh edge habitat (2). Additionally, SAV releases oxygen into the water, while subtidal oyster rocks with vertical relief provide refuge for crabs and other invertebrates during anoxic events. Maintaining these habitat complexes will not only enhance conditions needed for blue crab as well as numerous other fishery and non-fishery species, but benefit the entire coastal ecosystem. It is well recognized that crab dredging, which is designed to dig up overwintering crabs from the mud, causes more severe damage to benthic habitat than any other gear actively used in NC, particularly to SAV and oysters (4; 5; 6; 2). Since there are less habitat damaging methods available to harvest crabs, the CHPP recommended in 2010 that crab dredging be prohibited.

Table 4.6.1. Annual blue crab landings (pounds) and value ($) from dredges, trawls, and overall, 1995 – 2017. Confidential data is given as less-than a rounded value.

	Crab Dredge		Oyster Dredge		Crab Trawl		Shrimp Trawl		Other Gears		Total	
Year	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)
1995	7,403	4,220	541	308	1,065,578	736,465	225,228	137,832	45,144,790	35,360,461	46,443,541	36,239,286
1996	9,590	4,569	<250	<150	3,090,591	1,733,261	304,450	161,274	63,675,568	41,143,330	67,080,200	43,042,434
1997	2,567	1,328	<250	<150	3,291,288	2,019,161	312,823	189,607	52,483,431	35,475,942	56,090,109	37,686,039
1998	0	0	171	95	3,086,044	1,985,076	554,043	311,755	58,435,913	42,662,715	62,076,170	44,959,640
1999	0	0	213	110	1,817,726	1,149,536	281,370	159,002	55,447,368	36,503,552	57,546,676	37,812,199
2000	0	0	591	390	941,824	759,561	209,247	154,819	39,486,723	36,522,957	40,638,384	37,437,728
2001	7,101	5,524	358	226	997,763	778,549	186,053	122,757	30,989,115	31,324,540	32,180,390	32,231,596
2002	328	239	129	72	1,119,239	657,628	160,664	96,679	36,455,959	32,393,815	37,736,319	33,148,432
2003	8,704	5,016	<1,500	<1,000	1,259,721	850,996	305,582	193,035	41,195,791	36,059,046	42,769,797	37,108,093
2004	4,838	3,357	2,113	1,343	896,554	539,501	163,715	74,368	33,063,388	23,847,274	34,130,608	24,465,843
2005	<1,500	<1,000	6,007	3,030	388,996	365,568	61,807	31,144	24,973,309	19,874,171	25,430,119	20,273,913
2006	<100	<75	2,643	1,185	138,708	90,925	37,027	14,754	25,164,781	16,980,531	25,343,158	17,087,395
2007	2,656	2,742	572	402	28,789	30,811	31,772	15,613	21,361,171	21,382,387	21,424,960	21,431,955
2008	0	0	225	113	1,557,934	863,662	4,244	3,380	31,354,288	26,688,232	32,916,691	27,555,386
2009	7,981	7,166	<100	<75	913,928	556,676	17,298	11,484	28,768,025	26,853,669	29,707,232	27,428,995
2010	52,769	46,163	18,567	15,426	289,399	248,343	11,575	10,395	30,310,701	26,223,464	30,683,011	26,543,791
2011	6,843	4,348	31,861	19,584	201,940	112,871	5,785	4,902	29,788,963	21,140,558	30,035,392	21,282,264
2012	2,335	1,854	2,756	2,108	10,075	11,964	24,146	11,303	26,746,357	22,779,708	26,785,669	22,806,938
2013	0	0	1,305	1,412	56,470	59,638	41,609	31,125	22,103,238	29,914,273	22,202,623	30,006,447
2014	<50	<50	7,372	8,908	39,902	45,390	48,482	36,271	26,135,209	33,936,824	26,230,965	34,027,403
2015	<2,000	<1,500	5,216	5,395	187,107	212,337	12,551	14,187	31,928,245	33,492,505	32,134,501	33,724,424
2016	1,962	1,529	1,404	1,576	165,569	135,633	17,051	14,555	25,274,871	23,959,423	25,459,475	24,112,715
2017	0	0	1,302	1,413	120,135	123,169	17,771	22,045	19,134,770	22,072,006	19,273,156	22,217,815
Average 1995-2017	5,099	3,905	7,008	5,598	941,969	611,597	131,926	79,230	34,757,477	29,417,017	35,839,963	30,114,380
Average 2013-2017	671	548	3,320	3,741	113,473	114,916	27,493	23,637	24,915,267	28,675,006	25,060,144	28,817,761

Table 4.6.2. Average monthly blue crab landings (pounds) and value from crab and oyster dredges in the past ten years (2008-2017).

	Crab Dredge		Oyster Dredge		Total	
Month	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)
January	4,016	3,316	1,851	1,344	5,867	4,660
February	3,313	2,911	2,041	1,547	5,436	4,540
March	0	0	656	562	656	562
April	0	0	25	16	25	16
October	0	0	5	3	5	3
November	0	0	1,303	1,060	1,303	1,060
December	0	0	1,126	1,065	1,126	1,065

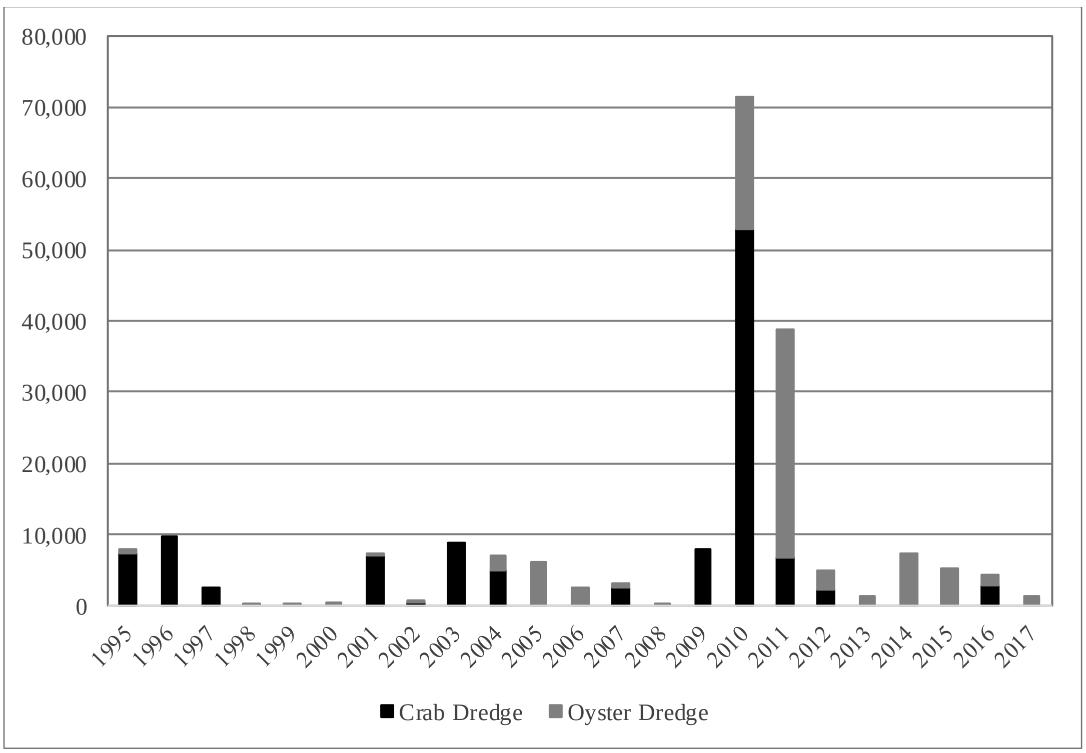

Figure 4.6.1. Blue crab landings from crab and oyster dredges, 1995-2017.

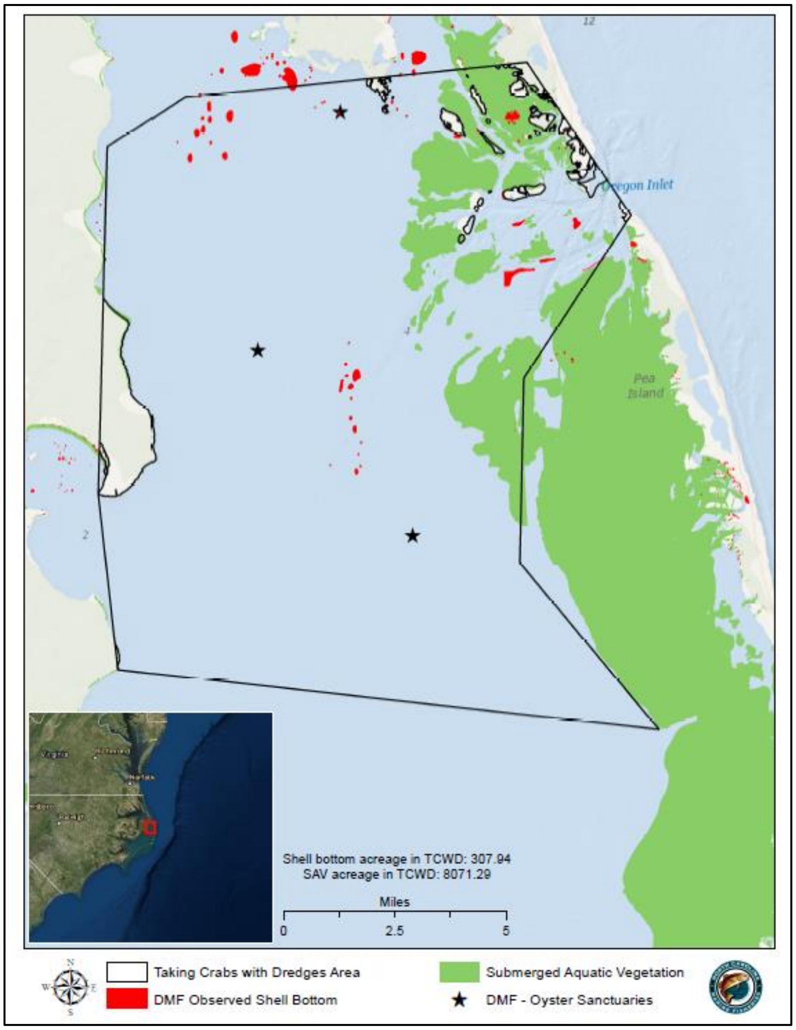

Figure 4.6.2. Location of SAV, shell bottom, and oyster sanctuaries within the designated crab dredge area in northern Pamlico Sound.

Allowing crab harvest in the oyster dredge fishery has enforcement issues. NCMFC Rule 15A NCAC 03L .0203 (a)(2) states that the weight of the crabs shall not exceed 50% of the total weight of the combined oyster and crab catch, or 500 pounds, whichever is less. However, Marine Patrol measures by volume (bushels), not weight, so enforcement of the weight criteria is difficult. The weight of a bushel can be highly variable, making conversion from bushels to weight inaccurate. Additionally, allowing the harvest of crabs could entice fishermen to dredge in soft bottom adjacent to the oyster rock once they have finished oyster fishing until they reach their trip limit. Oyster dredging rules have many requirements (e.g., deploying dredge from the side of the vessel, culling on site) to keep dredging activity on the rock rather than digging along the edges and dispersing culled shell material onto soft sediment. Targeting crabs in the soft bottom adjacent to the oyster rock was not the intent of this rule and could lead to unlawful oyster dredging operations, suspended sediments in the water column, siltation, and damage to shell bottom on the growing edge of the structure. Since the majority of crabs harvested in the oyster dredge fishery are mature females in some areas (7), allowing blue crab harvest can lead to additional stress on the spawning stock and reduce reproductive output needed to increase the blue crab population.

Blue crab landings taken with oyster and crab dredges, as well as effort, are not a significant contributor to the overall blue crab fishery. Landings accounted for only 0.02% of the total blue crab landings over the past five years (2013-2017; average annual value $4,711). Landings from trawls were similarly low. In contrast, while remaining gears, primarily pots, accounted for 99.42%. The number of participants in the crab dredge fishery in the past five years has ranged from 0-6, and in the oyster dredge fishery ranged from 119-268 (Table 4.6.3).

Table 4.6.3. Participation in the crab dredge, oyster dredge, and crab trawl fisheries

	Crab Dredge		Oyster dredge		Crab and Peeler Trawls	
Year	Participants	Trips	Participants	Trips	Participants	Trips
1995	9	36	15	88	225	2,133
1996	5	27	2	3	297	4,198
1997	3	11	6	31	309	4,916
1998	0	0	68	671	270	5,543
1999	0	0	80	940	208	3,447
2000	0	0	50	392	179	2,186
2001	8	26	58	822	200	2,517
2002	3	5	48	621	135	1,027
2003	3	14	56	892	137	1,672
2004	7	19	123	1,750	172	1,744
2005	2	7	167	2,333	99	1,092
2006	1	1	151	2,486	40	296
2007	3	18	150	1,729	32	157
2008	0	0	159	2,688	44	312
2009	9	44	258	4,481	59	473
2010	20	146	506	10,655	55	295
2011	12	69	355	7,400	41	253
2012	3	4	184	2,264	16	45
2013	0	0	220	3,763	18	104
2014	1	1	268	5,705	32	129
2015	2	14	212	4,028	50	384
2016	4	4	177	2,684	45	404
2017	0	0	119	1,540	32	317
Average 1995-2017	4	19	149	2,520	117	1,463
Average 2013-2017	1	4	199	3,544	35	268

Due to the location and season of the crab and oyster dredge fisheries, crab landings are primarily mature females in some areas. Converting pounds to numbers of individual crabs and using the average over the last five years, this equates to approximately 19,524 crabs/year taken with crab dredge and 49,797 crabs/year taken with oyster dredge. While these gears account for a small portion of the overall landings, closing the harvest of blue crabs from these gears would allow more mature females to reproduce the following season. Considering management changes to prohibit the taking of blue crabs with crab and oyster dredges or lowering the crab catch limit from oyster dredges makes ecological sense with relatively minor economic impact (Table 4.6.1).

Trawling

Another example of a potential gear closure would be to limit crab trawling in the Pamlico, Pungo, and Neuse rivers to the current shrimp trawl lines in each river, or completely prohibit their use statewide.

Over the past five years there have been minimal landings of blue crabs from crab and shrimp trawls in the Pamlico, Pungo, and Neuse rivers (Table 4.6.4). Figures 4.6.3 and 4.6.4 show the current crab trawl boundary lines and the current shrimp trawl boundary lines for the Pamlico and Neuse river systems. Prohibiting crab trawling in the upper areas of the rivers would eliminate all bottom disturbing fishing gear in these areas.

Mobile disturbing bottom gear such as trawls and dredges can adversely impact fish habitat by re-suspending sediments and any associated pollutants into the water column. Suspended sediments can clog gills of juvenile and larval fish, reduce primary production in the water column or benthic community, and release toxins where they can be taken up by estuarine organisms. Dragged gear can cause structural damage or loss to benthic habitats such as SAV and shell bottom. Reviews of fishing gear impacts have categorized crab dredges and crab/shrimp trawls as having more severe impacts than other fishing gear, although the extent varies by the gear configuration, proximity of benthic habitats, and life stages of fish present (*4*; *2*). Refer to the section "Fishery Impacts to the Ecosystem" for more details.

Limiting bottom disturbance could improve habitat conditions not only for blue crab but many other estuarine fishery species and provide additional protection to significant portions of NCMFC approved Strategic Habitat Areas (SHA). Strategic Habitat Areas are complexes of high quality, diverse habitats that provide exceptional ecological functions to important fishery species. These areas have been identified through a comprehensive spatial analysis and represent priority areas for protection and enhancement. Strategic Habitat Areas located within the Pamlico and Neuse systems, as well as other areas open to trawling are shown in Figures 4.6.5 and 4.6.6.

Statewide blue crab landing from crab trawls and shrimp trawls have accounted for only 0.05% and 0.1%, respectively, of the total blue crab harvest over the past five years (Table 4.6.1). The prohibition of blue crab harvest by use of crab and shrimp trawl, as well as crab dredge would have minimal economic effects on the fishery, while addressing fishery and habitat level concerns of these gears.

Table 4.6.4. Annual crab landings (pounds) from crab and shrimp trawls in the Pamlico, Pungo, and Neuse rivers, 1995 – 2017. Confidential data is given as less-than a rounded value.

	Crab Trawl			Shrimp Trawl		
Year	Neuse River	Pamlico River	Pungo River	Neuse River	Pamlico River	Pungo River
1995	35,618	154,056	267,400	34,019	7,452	0
1996	212,979	486,829	298,657	50,710	0	1,412
1997	411,998	400,922	401,605	57,808	11,144	2,883
1998	306,178	559,477	203,993	40,883	1,526	0
1999	243,473	457,575	208,396	31,644	4,264	1,123
2000	47,674	104,043	78,764	11,144	1,472	714
2001	41,030	43,164	17,625	5,390	2,284	462
2002	2,877	4,506	142,682	11,985	1,532	1,027
2003	41,411	139,386	81,037	6,410	<500	<3,000
2004	35,363	76,990	63,604	12,444	0	0
2005	18,982	159,327	8,857	4,992	<500	<500
2006	6,057	19,512	<5,000	1,195	76	<500
2007	1,283	<500	<500	<1,000	<500	0
2008	<500	<500	<500	900	0	0
2009	<500	<500	<500	105	<2,000	0
2010	<500	<500	0	<500	0	0
2011	0	<500	0	<500	<500	0
2012	<500	0	0	0	<500	0
2013	0	0	0	904	0	0
2014	<500	0	0	2,561	0	0
2015	<500	<500	<500	451	<500	0
2016	<1000	<500	<500	<500	<500	0
2017	<500	<500	0	360	0	0

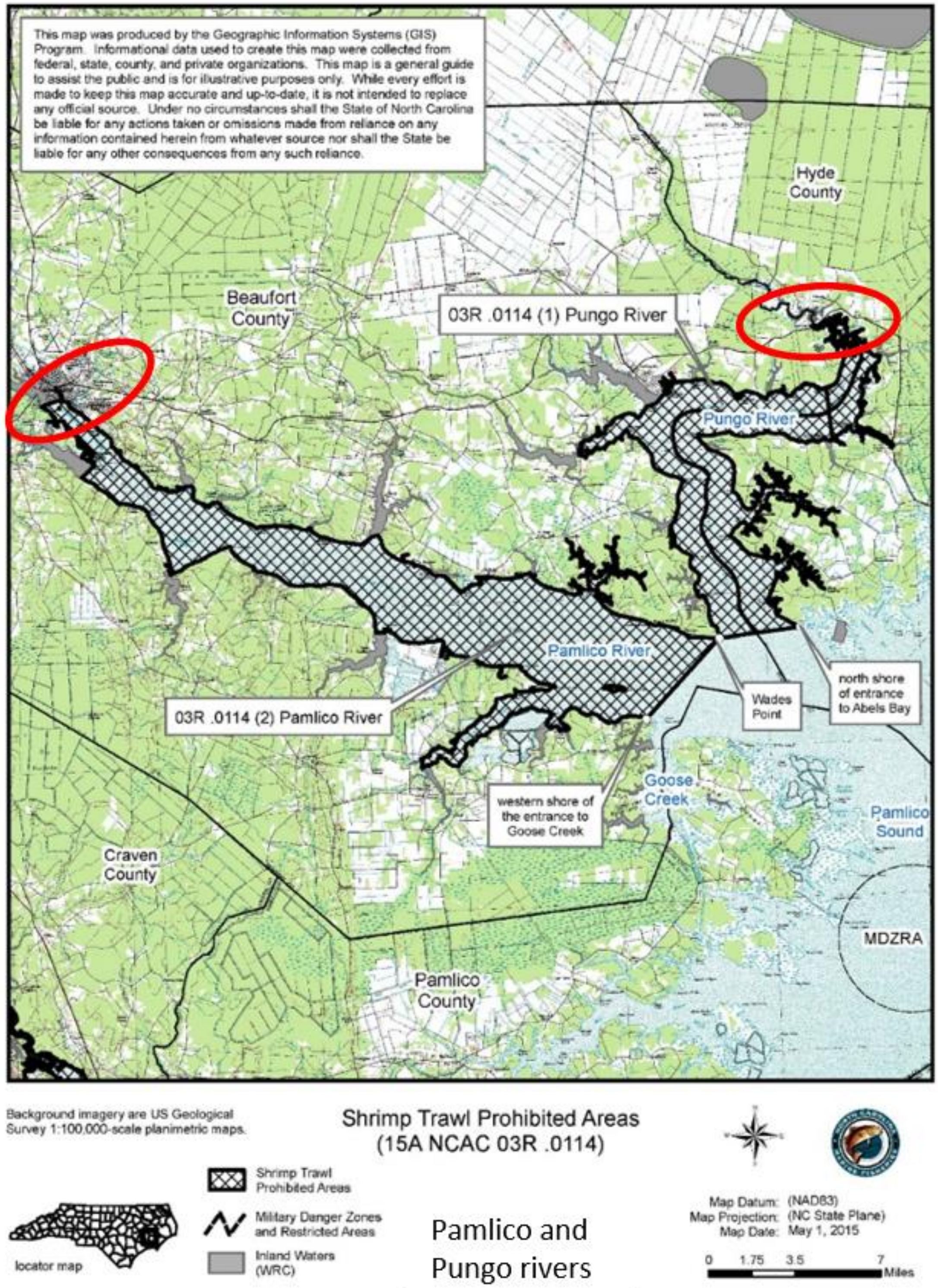

Figure 4.6.3. Areas where crab trawling is allowed within shrimp trawl prohibited areas in the Pamlico and Pungo rivers (hatched area). Red ovals mark the upper limit of trawling.

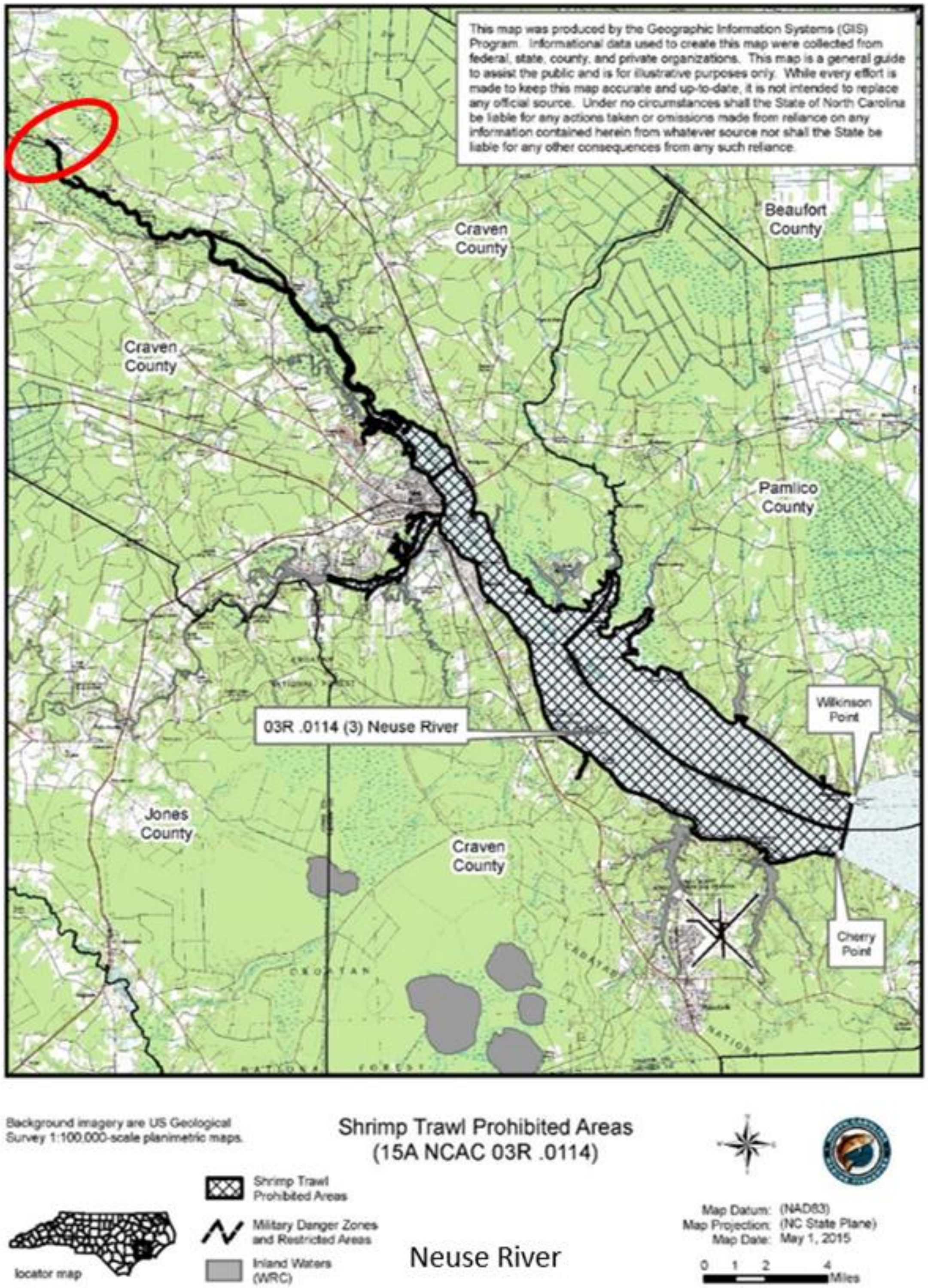

Figure 4.6.4. Area where crab trawling is allowed within the shrimp trawl prohibited area in the Neuse River (hatched area). Red oval marks the upper limit of trawling.

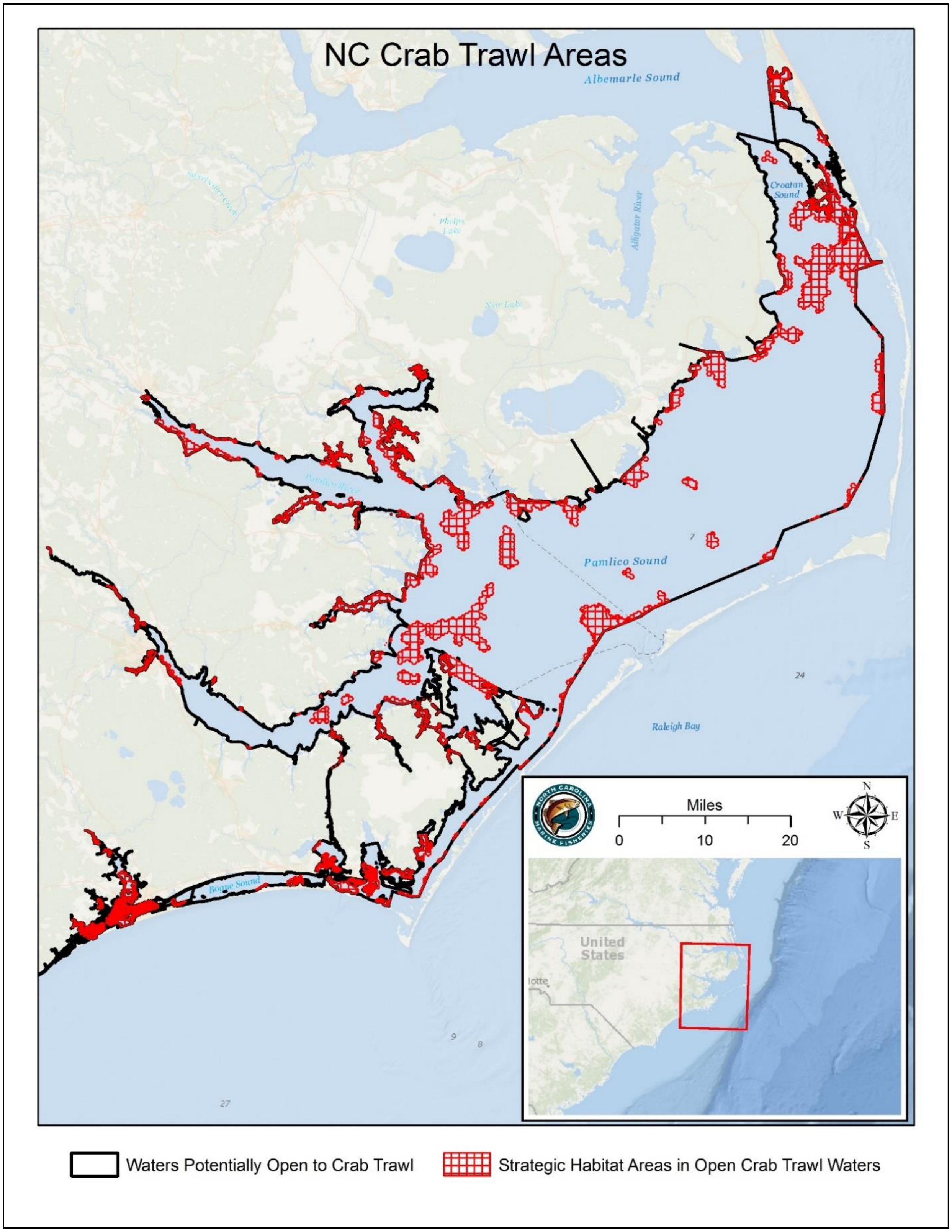

Figure 4.6.5. Current statewide crab trawl boundary lines (Bogue Sound North) with designated strategic habitat areas (SHA) shaded by region.

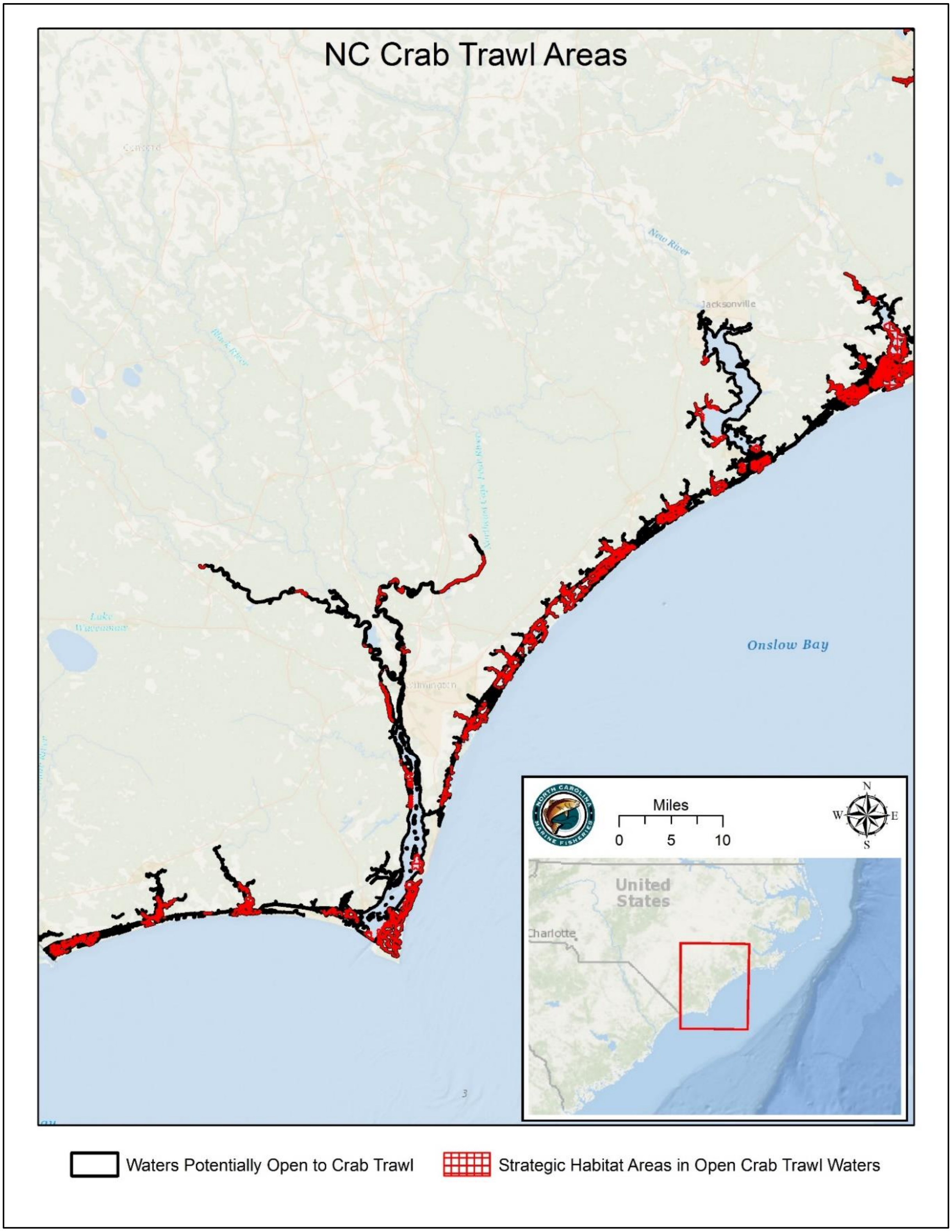

Figure 4.6.6. Current statewide crab trawl boundary lines (South of Bogue Sound) with designated strategic habitat areas (SHA) shaded by region.

VII. MANAGEMENT OPTIONS AND IMPACTS

(+ Potential positive impact of action)
(- Potential negative impact of action)

1. Limit the taking of crabs with dredges
   a. Prohibit the taking of crabs with crab dredges
   b. Prohibit taking of crabs as incidental bycatch during oyster dredging operations
   c. Prohibit the taking of crabs with crab dredges and oyster dredges
   d. Reduce the trip limit of crabs from oyster dredges to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less

   - \+ Will reduce habitat damage to SAV, oyster reefs, and oyster sanctuaries in the crab dredge area
   - \+ May increase abundance of mature females helping to rebuild the spawning stock
   - \+ Will avoid additional impact to oyster rocks and soft bottom
   - \+ Will avoid unlawful targeting of blue crabs in the oyster dredge fishery
   - \+ Easier to enforce
   - – Management change required
   - – Could lead to some waste of crabs in the oyster fishery
   - – Decreased harvest with economic loss to the fishery

2. Limit the use of crab trawls spatially
   a. Prohibit the use of crab trawls in areas where shrimp trawls are already prohibited in the Neuse and Tar-Pamlico rivers (15A NCAC 3R .0114)
   b. Prohibit the use of crab trawls coastwide

   - \+ Will reduce habitat damage to SHAs and other bottom habitat in crab trawl areas
   - \+ May increase abundance of mature females helping to rebuild the spawning stock
   - – Decreased harvest with economic loss to the fishery
   - – Some regions may be impacted more than others

VIII. RECOMMENDATION

NCMFC selected management strategy

- Option 1a: Retain prohibiting taking of crabs with crab dredges, established in the 2016 Revision
- Option 1d: Reduce the bycatch limit of crabs from oyster dredges to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less
- Option 2a: Prohibit the taking of crab by trawls in areas where the taking of shrimp with trawls are already prohibited in the Pamlico, Pungo, and Neuse rivers

NCMFC Summary
To reduce habitat impacts and improve spawning potential by mature females, the NCMFC adopted management strategies for bottom disturbing gear. The selected prohibition of taking

crabs with crab dredges was part of the 2016 Revision and addressed a concern of targeting female crabs in soft bottoms where they bed in the cooler months. Additionally, the NCMFC recommended to reduce the crab bycatch limit from oyster dredges with the intention to keep dredging activities on the reefs targeting oysters with some allowance for incidental crab catch from the reef. To further protect habitat and have consistent regulations for crab and shrimp trawls, the NCMFC adopted Option 2a, aligning rules for the taking of crabs and shrimp by trawls in the Pamlico, Pungo, and Neuse rivers. Initial May 1, 2020 implementation of the adopted measures is found in Proclamation M-8-2020 and SH-1-2020.

See Appendix 4.7 for a summary of all comments and recommendations gathered from NCDMF, the NCMFC advisory committees, and public for the Blue Crab FMP Amendment 3.

IX. LITERATURE CITED

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APPENDIX 4.7: SUMMARY OF ADVISORY COMMITTEE AND NCDMF RECOMMENDATIONS FOR ISSUE PAPERS IN AMENDMENT 3

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Table 4.7.1. Summary of the NCDMF, Blue Crab FMP and standing and regional AC, and Constant Contact online questionnaire recommendations f or Amendment 3 to the Blue Crab FMP. Highlighted text denotes changes to the NCDMF and Blue Crab FMP AC recommendations since the last commission meeting in August 2019. **Bolded** items are measures initially in effect through the 2016 Revision to Amendment 2 of the Blue Crab FMP. *Only management options supported by more than 50% of respondents were included for the Constant Contact online questionnaire.

Issue	NCDMF	Blue Crab FMP AC	Northern Regional AC	Southern Regional AC	Shellfish/Crustacean AC	Habitat and Water Quality AC	Constant Contact Questionnaire*
Sustainable Harvest	Minimum harvest reduction of 2.2% (50% probability of success). The division encourages the commission to consider a reduction of at least 5.9% (90% probability of success) and to include: **1) prohibit immature female hard crab harvest**, 2) 5-inch minimum size limit for mature females, and 3) a continuous closure period that results in a reduction of at least 4.6% to make up the remainder of the preferred reduction	Option 18.3: 1) North of the Highway 58 Bridge: January 1 through January 31 closed season, 6.75" mature female hard crab maximum size limit, and **prohibit immature female hard crab harvest** and 2) South of the Highway 58 Bridge: March 1 through March 15 closed season and prohibit immature female hard crab harvest (3.2% harvest reduction; 50% probability of success)	Support Blue Crab AC recommendation	Recommend Dec.-Jan. closure North of Hwy 58 Bridge and a Jan. closure South of Hwy 58 Bridge; 5-inch mature female minimum size limit; **prohibit harvest of immature female hard crabs** (4.3% harvest reduction; 67% probability of success)	Recommend tabling FMP process until the stock assessment is updated with data through 2019 to see the effects of the 2016 regulations	No position	Mature female size limit (67%)
	Recommended closure period will replace current pot closure period and will remain closed for the entire period	Recommended season closure will replace current pot closure period and will remain closed for the entire time period	Support NCDMF recommendation for adaptive management framework	**Maintain 5% cull tolerance**	Support consideration of habitat as part of the overall strategy for management of the blue crab fishery		Limit harvest of immature female hard crabs (67%)
	Maintain 5% cull tolerance established in 2016 Revision	**Maintain 5% cull tolerance established in 2016 Revision**		Leave adaptive management decision to MFC			
	Adopt proposed adaptive management framework which was updated to allow management measures to possibly be relaxed if the assessment update shows the stock is not overfished and overfishing is not occurring	Adopt proposed adaptive management framework and allow measures to be relaxed is assessment update says stock is not overfished and overfishing is not occurring					
		Recommend updating the stock assessment once 2019 data is available					

Issue	NCDMF	Blue Crab FMP AC	Northern Regional AC	Southern Regional AC	Shellfish/Crustacean AC	Habitat and Water Quality AC	Constant Contact Questionnaire*
Qualitative Management	**Option 2a: increase number of cull rings in pots to 3**	**Leave in existing rules put in in 2016** and do not adopt anything else at this time, except with 2 options on cull rings: 1) 2 cull rings in proper corner placement or 2) **keeping the 3 cull rings with 1 in proper placement**	Support Blue Crab AC recommendation	Support Blue Crab AC recommendation regarding number and placement of cull rings	No position	No position	Limit the harvest of sponge crabs (100%)
	Option 3b: two cull rings placed within one full mesh of corner and the apron on opposite outside panels in the upper chamber			Support NCDMF recommendation for option 4c (remove cull ring exemptions)			Minimum size limit for soft and peeler crabs (61%)
	Option 4c: remove cull ring exemptions for Newport River and eastern Pamlico Sound and prohibit designation of exempt areas in future			**Support option 7a (prohibit dark sponge crab harvest during month of April)**			Impose a limit on the number of crab pots fished (61%)
	Option 7c: prohibit harvest of sponge crabs year-round						
	Option 8a: establish 3" minimum size limit for peeler and soft crabs						
Water Quality	Support all management options presented	Support all management options in this paper	Support Blue Crab AC recommendation	Support NCDMF and Blue Crab AC recommendations	No position	Recommend accepting the water quality recommendation from the Blue Crab AC and adding the Habitat and Water Quality AC to the reporting groups	Support recommendations to address water quality concerns (89%)
	Recommend Option 4 as the highest priority	Support making the highest priority option four tasking the CHPP steering committee to what is suggested here and follow up with each of the other recommendations as that step is justified					

Issue	NCDMF	Blue Crab FMP AC	Northern Regional AC	Southern Regional AC	Shellfish/Crustacean AC	Habitat and Water Quality AC	Constant Contact Questionnaire*
	Division habitat staff shall regularly report back to the Habitat and Water Quality and the Shellfish/Crustacean ACs with progress on each management option	Have the habitat staff report back to the Shellfish/Crustacean AC with progress					
Spawning Sanctuaries	Expand boundaries as presented for Oregon, Hatteras, Ocracoke, and Barden inlets	Keep Oregon, Hatteras, and Ocracoke the same and change Drum and Barden to proposed boundaries	Split consensus on whether to expand or keep boundaries for existing spawning sanctuaries	Support Blue Crab AC recommendations	No position	Recommend keeping Oregon, Hatteras, and Ocracoke spawning sanctuary boundaries the same	Establish new crab spawning sanctuaries at all inlets without a crab spawning sanctuary (61%)
	Move boundary for Drum Inlet crab spawning sanctuary as presented	Add spawning sanctuaries from Beaufort through Tubbs inlets using AC recommended boundaries with a closure period of March 1 through Oct. 31 with same restrictions as existing sanctuaries	Support NCDMF and Blue Crab AC recommendation to move Drum Inlet spawning sanctuary			Support NCDMF and Blue Crab AC recommendation to move Drum Inlet spawning sanctuary	Establish a crab spawning sanctuary to serve as a migration corridor in Croatan Sound (56%)
	Concur with AC recommendations for Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Shallotte, Lockwood Folly, and Tubbs inlets		Support Blue Crab AC recommendation for southern spawning sanctuary boundaries (excluding Cape Fear River)			Support Blue Crab AC recommendation for southern spawning sanctuary boundaries (excluding Cape Fear River)	
	Use NCDMF recommended boundary for Cape Fear River Inlet crab spawning sanctuary		Support NCDMF recommended boundary for Cape Fear River spawning sanctuary			Support NCDMF recommended boundary for Cape Fear River spawning sanctuary	
	Concur with AC recommendation of a March 1 through October 31 closure for Beaufort Inlet through Tubbs Inlet sanctuaries with same restrictions as existing crab spawning sanctuaries		Recommend March 1 - Oct. 31 closure for spawning sanctuaries south of the Hwy 58 Bridge (Bogue through Tubbs inlets). Beaufort Inlet would have same closure period as existing spawning sanctuaries (March 1 - Aug. 31)			Recommend March 1 - Oct. 31 closure for spawning sanctuaries south of the Hwy 58 Bridge (Bogue through Tubbs inlets). Beaufort Inlet would have same closure period as existing spawning sanctuaries (March 1 - Aug. 31)	

Issue	NCDMF	Blue Crab FMP AC	Northern Regional AC	Southern Regional AC	Shellfish/Crustacean AC	Habitat and Water Quality AC	Constant Contact Questionnaire*
	Establish a crab spawning sanctuary to serve as a migration corridor on the east side of Croatan Sound, as presented and in conjunction with expanding the Oregon Inlet spawning sanctuary, closed to blue crab harvest from May 16 through July 15 and with the same restrictions as existing sanctuaries		Do not support a spawning sanctuary (migration corridor) in Croatan Sound			Do not support a spawning sanctuary (migration corridor) in Croatan Sound	
Diamondback Terrapin	Use the criteria as outlined in this paper for the establishment of Diamondback Terrapin Management Areas (DTMAs)	Use science on locally specific pot funnel design to reduce terrapins and identify individual creeks with terrapin population hot spots that would be closed to potting	Support NCDMF recommendation	Support NCDMF recommendation	No position	No position	Support criteria for designating Diamondback Terrapin Management Areas (59%)
Bottom Disturbing Gear	**Option 1a: prohibit taking of crabs with crab dredges**	Not adopt any of the recommended management options on crab dredge and leave crab trawl lines as is	**Support NCDMF recommendation Option 1a (prohibit taking of crabs with crab dredges)**	Support Blue Crab AC recommendation	No position	**Recommend accepting NCDMF recommendation 1a**	Prohibit taking of crabs with crab dredges and oyster dredges (67%)
	Option 1d: reduce the bycatch limit from oyster dredges to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less		Do not support reducing bycatch limits in oyster dredges until landings are examined			Recommend accepting NCDMF recommendation 1d	Reduce the bycatch limit of crabs from oyster dredges to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less (78%)

Issue	NCDMF	Blue Crab FMP AC	Northern Regional AC	Southern Regional AC	Shellfish/Crustacean AC	Habitat and Water Quality AC	Constant Contact Questionnaire*
	Option 2a: prohibit use of crab trawls in areas where shrimp trawls are already prohibited in the Pamlico, Pungo, and Neuse rivers		Split consensus on support of NCDMF recommendation Option 2a (prohibit use of crab trawls above shrimp trawl lines in Pamlico, Pungo, and Neuse rivers)			Do not recommend accepting NCDMF recommendation 2a	Prohibit use of crab trawls coastwide (53%)