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ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

May 17, 2018

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Catherine Blum, Fishery Management Plan and Rulemaking Coordinator
Fisheries Management Section

SUBJECT: Fishery Management Plan Update

This memo provides an overview on the status of the North Carolina fishery management plans for the May 2018 commission meeting. No action is required by the commission.

The review process for the **Blue Crab Fishery Management Plan** is underway. The next advisory committee meeting will be held in early May. Agenda items include a general overview of the division's efforts to streamline fishery management plan documents. There will also be a presentation reviewing the results of the blue crab stock assessment. This follows the stock assessment peer review workshop that was held March 27-29 in New Bern, NC. A memo summarizing the stock assessment process and the results is included in your briefing book, along with the full stock assessment report. The commission will receive a presentation at its May meeting.

The commission gave its final approval of the **Shrimp Fishery Management Plan** Amendment 1 and associated rules Feb. 19, 2015. One of several strategies approved in Amendment 1 was the convening of an industry stakeholder group to initiate a three-year study to test bycatch reduction devices to reduce bycatch to the extent practicable, with a 40-percent target reduction. The Shrimp Bycatch Reduction Industry Work Group was formed and gear testing was conducted from 2015 through 2017. An information paper summarizing the final results of the gear testing and the work group's recommendation is included in your briefing book. The commission will receive a presentation at its May meeting. Recommendations from the industry workgroup on bycatch reduction in shrimp trawls that may be adopted by the commission can be implemented by existing proclamation authority.

After completing the annual update in July 2017 for the **Striped Mullet Fishery Management Plan**, the stock status was moved from "viable" to "concern" because 2016 commercial landings fell below the minimum landings trigger established in Amendment 1 to the plan. In accordance with the plan, the division reviewed striped mullet data in more detail to determine what factors are responsible for this decline and presented preliminary data analysis and recommendations at the November 2017 commission meeting. At the February 2018 meeting, the commission received a presentation on the completed data analysis, including preliminary 2017 striped mullet commercial landings and fishery independent data, as well as recommendations for steps to move forward.

Based on results of the completed data analysis, the striped mullet stock has likely declined since completion of the 2013 stock assessment (terminal year 2011) and management action is likely warranted. The division is updating the 2013 stock assessment model to include data through 2017 prior to taking any management action. The target for model completion is May 2018. As an assessment update, there will be no changes to model parameters and peer review will not be required, as the configuration of the model that previously passed peer review will be maintained. If results of the update indicate overfishing is occurring in the striped mullet fishery, management options will be developed to maintain harvest at sustainable levels.

After management options are developed, the division will select a preferred option. Per the fishery management plan, management options will then be brought to an advisory committee, specifically the Finfish and regional advisory committees, to receive input. Recommendations will be presented to the commission at its August 2018 business meeting. At that meeting, the commission will be asked to decide on management options to be implemented by existing proclamation authority. Implementing management measures in August 2018 provides adequate time for management measures to be in place prior to the peak of the 2018 fishing season, which occurs in the fall.

The review process for the **Southern Flounder Fishery Management Plan** is underway. The second advisory committee meeting was held March 21 when the committee received a presentation reviewing the data sources considered for the southern flounder stock assessment. The next advisory committee meeting will be held in early May. Agenda items include a general overview of the division's efforts to streamline fishery management plan documents. There will also be a presentation to provide the results of the coastwide stock assessment. The assessment was conducted by a group of representatives from North Carolina, South Carolina, Georgia and Florida.

At the February 2018 commission meeting, the division gave a presentation summarizing the results of the coastwide stock assessment, peer review evaluation and recommendations for steps to move forward. The review panel accepted the stock assessment for management contingent on updating the model with data through 2017 (not just 2015 as it was reviewed) to provide the best, most up-to-date estimate of stock status for management. Next steps include updating the approved model with the additional two years of data. The division also plans to include updated Marine Recreational Information Program estimates, as requested by the review panel, if they are available as scheduled in July 2018. This update can move forward while continuing with the review and amendment of the plan.

For the review of the **Estuarine Striped Bass Fishery Management Plan**, stock assessments for the Central Southern Management Area stocks and the Albemarle Sound Management Area and Roanoke River Management Area stock that began in 2017 are continuing. This is a joint plan with the Wildlife Resources Commission, so all updates and reviews are joint efforts by both agencies. Preparations are underway for holding the stock assessment methods workshop with the plan development team. Multiple assessment techniques will be considered given the number of systems to assess and the variety of data sources for each system.

ROY COOPER
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MICHAEL S. REGAN
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Director

May 16, 2018

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Yan Li, Stock Assessment Scientist
Jason Rock, Blue Crab Species Lead
Fisheries Management Section

SUBJECT: North Carolina Blue Crab Stock Assessment

Since late 2016, the Division of Marine Fisheries has been working to develop a quantitative stock assessment for the North Carolina blue crab stock. The effort was prompted by a motion from the Marine Fisheries Commission at its August 2016 business meeting to move up the review of the Blue Crab Fishery Management Plan to begin in 2016. The division's Blue Crab Plan Development Team (PDT)* held their first meeting in November 2016 to begin the stock assessment process. This process concluded with an in-person peer review workshop, that was open to the public and held in New Bern in March 2018.

During the development of the stock assessment, the PDT followed the division's stock assessment standard operating procedures. The PDT thoroughly reviewed datasets including:

- Commercial landings and discards,
- Recreational landings and discards,
- Survey indices of abundance, and
- Biological data (e.g., carapace width, weight, sex, maturity).

Selected data were incorporated into a sex-specific two-stage model (based on the catch-survey analysis) that was appropriate for the available data. The time series selected for the assessment was 1995 through 2016 and was based on available data. Data from four fishery-independent surveys, as well as commercial landings, were included in the model.

In March 2018, the division held a three-day stock assessment peer review workshop where members of the PDT reviewed the model inputs and results with a panel of four experts on blue crab biology and/or stock assessment modeling. This in-person review workshop allowed discussion between the PDT and reviewers, enabling the reviewers to ask for and receive timely updates to the model as they evaluated sensitivity of the results to different model assumptions. The workshop also allowed the public the opportunity to observe the peer review process and better understand the development of stock assessments.

The results of the peer review workshop include:

- The reviewers accepted the sex-specific two-stage model as appropriate for management use. Results of the model indicate the stock is overfished* and overfishing* is occurring (Figure 1).
- The reviewers strongly recommended the model be updated at least once within the management time period of five years.
- The reviewers had concerns about possible over-parameterization, inconsistencies between survey and fishing time steps, and model assumptions about life history characteristics (e.g., natural mortality, growth), but additional model runs testing these concerns indicate the model is not influenced by these uncertainties.

A detailed report was produced by the peer review panel and is provided in the commission's briefing book.

Definitions

Plan Development Team(PDT): A group of staff, selected by the Division of Marine Fisheries Director for their expertise, that help develop and write a fishery management plan. Staff from other agencies, like the Wildlife Resources Commission, can also serve on a PDT for multi-jurisdictional plans, such as estuarine striped bass.

Overfished: The condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate for the recruitment class of a fishery to replace the spawning class of the fishery.

Overfishing: Fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest.

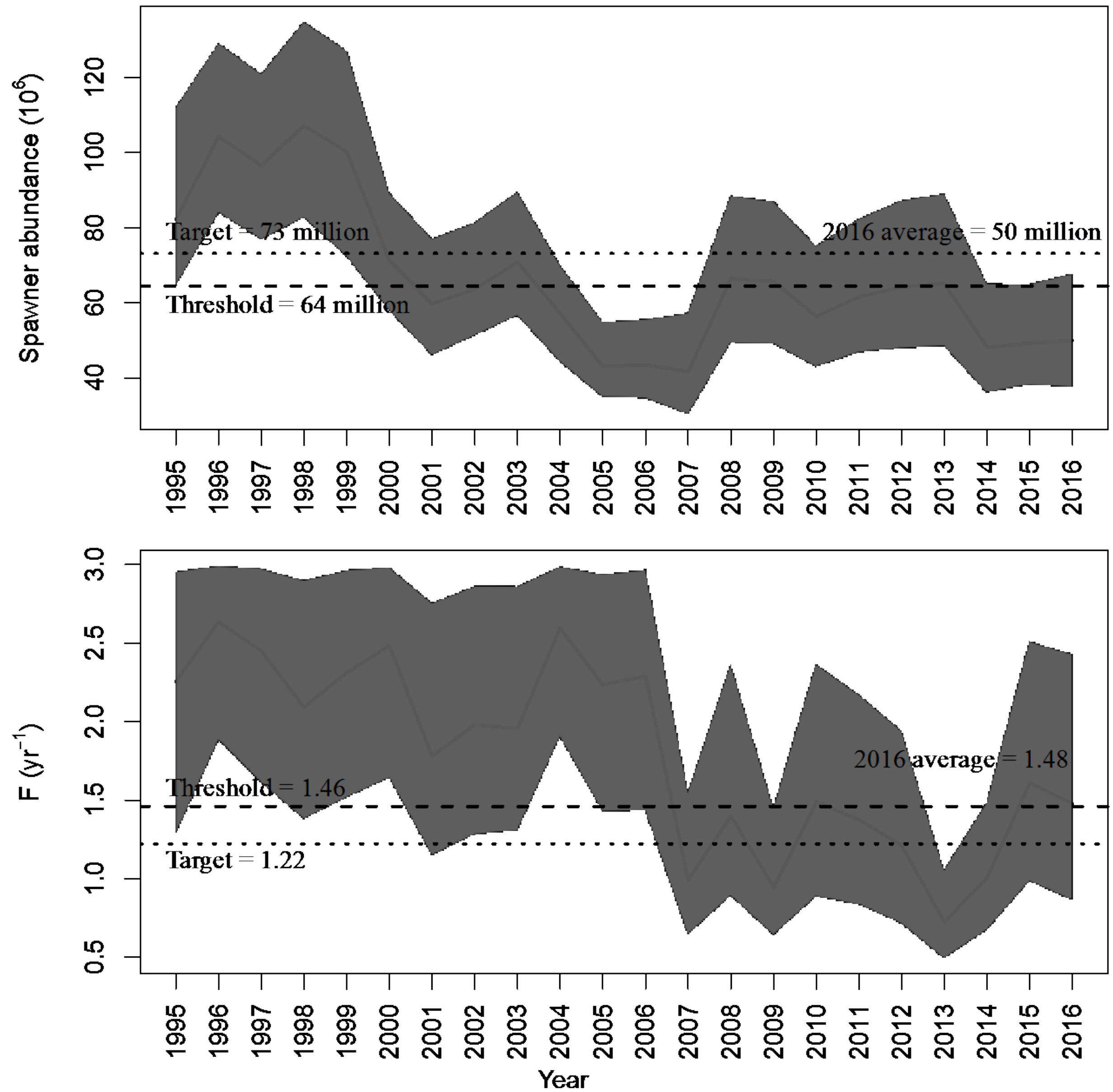

Figure 1. Estimated spawner abundance and fishing mortality (*F*) of North Carolina blue crab from the baseline model (Model 1), with lines representing posterior mean and shaded area representing 95% credible interval from the baseline model, Model 1. The threshold and target values are the posterior means.

Stock Assessment of the North Carolina Blue Crab (*Callinectes sapidus*), 1995–2016

Prepared by

North Carolina Division of Marine Fisheries
Blue Crab Plan Development Team

March 2018

NCDMF SAP-SAR-2018-02

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This report was prepared by the North Carolina Division of Marine Fisheries (NCDMF) Blue Crab Plan Development Team (PDT). The members are Jason Rock (co-lead), Corrin Flora (co-lead), Katy West (Mentor), Tina Moore, Joe Facendola, Jeff Dobbs, Laura Lee, Yan Li (lead analyst), Odell Williams, Alan Bianchi, Adam Stemle, and Anne Deaton. Thanks also to Kathy Rawls, NCDMF Fisheries Management Section Chief, and Catherine Blum, NCDMF Fishery Management Plan and Rulemaking Coordinator. Amy Flowers provided extensive assistance reviewing and editing the report.

We would like to thank the members of the NCDMF Management Review Team for their review and comments.

We are especially grateful to the external peer reviewers for offering their time and effort to review the blue crab stock assessment: Jeffrey Brust at the New Jersey Marine Fisheries Administration, Dr. Robert Leaf at The University of Southern Mississippi, Genine McClair at the Maryland Department of Natural Resources, and Dr. Ed Hale at the Delaware Division of Fish and Wildlife.

EXECUTIVE SUMMARY

The North Carolina Fisheries Reform Act requires that fishery management plans be developed for all commercially and recreationally significant species or fisheries that comprise State marine or estuarine resources. The goal of these plans shall be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Stock assessments are the primary tools used by managers to assist in determining the status of stocks and developing appropriate management measures to ensure the long-term viability of stocks.

In December 1998, the North Carolina Division of Marine Fisheries (NCDMF) adopted a Fishery Management Plan for the blue crab resource. The 2004 amendment (Amendment 1) adopted a spawning stock trigger and associated measures to protect the blue crab spawning stock. Amendment 2 (2013) repealed the spawning stock trigger and associated measures and adopted the traffic light approach in conjunction with an adaptive management plan to manage the blue crab stock. The 2016 revision to Amendment 2 implemented additional management measures (no harvest of immature females, no harvest of dark sponge crabs from April 1 to April 30, no targeted crab dredging, and adding a third cull ring to crab pots) because a management threshold identified in Amendment 2 was reached. Amendment 3 to the Fishery Management Plan is currently in development and this stock assessment was performed in support of the amendment.

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. 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.

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. Females had higher natural mortality estimates than males. 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 assessment (2016) was determined based maximum sustainable yield (MSY). Based on the results of this assessment, the North Carolina blue crab resource in 2016 is overfished with a probability of 0.98, given the average spawner abundance in 2016 being estimated at 50 million (below the threshold estimate of 64 million). And, overfishing is 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).

A number of recommendations for research and monitoring are offered to identify how deficiencies in the understanding of blue crab stock dynamics can be addressed.

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1 INTRODUCTION

1.1 The Resource

Blue crabs (*Callinectes sapidus*) are present from Nova Scotia to the northern coast of Brazil (Hay 1905; Guillory et al. 2001), supporting commercial and recreational fisheries along the Atlantic and Gulf coasts of the United States. The blue crab resource supports North Carolina's most valuable commercial fishery. Blue crabs are also commonly harvested by recreational fishermen in North Carolina.

Before 1995, the North Carolina Division of Marine Fisheries (NCDMF) did not have a sampling program dedicated to blue crabs, although limited information (landings statistics, juvenile abundance) was collected through other programs. Realizing the increasing importance of the blue crab fishery to the coastal economy, crabbers petitioned the North Carolina General Assembly in 1994 to allocate funding specifically for a blue crab assessment project. The resulting program focused on the establishment of fishery-dependent and -independent databases state-wide. Section 5.5 of the Fishery Reform Act of 1997 specifically required that the North Carolina Marine Fisheries Commission adopt a Fishery Management Plan (FMP) for the blue crab fishery by January 1, 1999. The plan was adopted by the Marine Fisheries Commission on December 11, 1998 (NCDMF 1998). All of North Carolina's state Fishery Management Plans are reviewed and updated every five years. If the FMP includes a stock assessment, the assessment is reviewed and updated at the same time as the FMP. The Blue Crab FMP was first amended December 3, 2004 (NCDMF 2004), followed by a second amendment in November 2013 (NCDMF 2013) and a revision to Amendment 2 was adopted in May 2016 (NCDMF 2016). Amendment 3 to the Blue Crab FMP is currently in development.

The last benchmark assessment (a comprehensive assessment conducted every five years by re-evaluating data and modeling methods) for North Carolina blue crab stock was conducted for management purposes in 2011 using a Traffic Light approach, as part of the review and amendment of the Blue Crab FMP (NCDMF 2011). An overfishing definition and status relative to overfishing could not be determined because available data were considered insufficient for estimating reliable fishing mortality rates. Therefore, the previous assessment considered the status of the North Carolina blue crab stock relative to overfishing as unknown. The previous assessment recommended defining the overfished condition based on the blue crab production characteristic of the Traffic Light such that when the proportion of red for the production characteristic is greater than or equal to the third quartile (>=0.75) for three consecutive years, the blue crab stock is considered overfished. Based on this definition, the results of the previous assessment suggested the North Carolina blue crab stock was not overfished.

However, the NCDMF currently lists the stock as one of "concern" in its annual stock status report (NCDMF 2017). The blue crab stock was listed as one of concern due to reduced commercial landings of hard blue crabs during 2000 through 2002, 2005 through 2007, 2012 through 2014 and 2016 following record-high commercial landings observed during 1996 through 1999. Commercial blue crab landings in 2016 were the third lowest on record during the 10-year period of 2007 through 2016.

The current stock assessment was developed as part of Amendment 3 to the Blue Crab FMP.

1.2 Life History

1.2.1 Stock Definitions

The blue crab, *Callinectes sapidus*, inhabits estuarine and nearshore coastal habitats throughout the western Atlantic and Caribbean from Maine to northern Argentina (Hay 1905; Williams 1984; Steele and Bert 1994; Guillroy et al. 2001), as well as the Gulf of Mexico (Darden 2004; McMillen-Jackson et el. 1994). The blue crab is common to all North Carolina coastal waters, but the largest aggregations tend to live in the Albemarle and Pamlico sounds and the tributaries associated with these regions.

Although blue crab larvae mix when in the larval stages on the continental shelf, the interchange of larvae from North Carolina and other states is assumed to be negligible. The unit stock includes blue crabs occurring in all coastal fishing waters of North Carolina. Tagging data from NCDMF indicate that while blue crabs do exhibit seasonal migrations, they remain in North Carolina estuarine or coastal waters (NCDMF 2008).

While there is little genetic information on blue crabs in North Carolina waters, genetic studies in the Chesapeake Bay (Zohar et al 2008), Florida (Darden 2004)., and their range in the eastern United States (McMillen-Jackson et al. 1994) indicate that populations of blue crab geographically close together are more genetically similar than populations geographically far apart.

1.2.2 Movements & Migration

The first larval stage (zoea) occurs offshore for several weeks where it undergoes several developmental stages before metamorphosing into megalopae (Van Engel 1958; Epifanio 1995). Because of the lack of inlets in Albemarle Sound, megalopae are transported through the inlets (primarily into Pamlico Sound, North Carolina) via onshore wind events and nighttime incoming spring tides (Forward et al. 2004), which may be overshadowed by tropical storm forcing, depending on frequency and wind direction (Eggleston et al. 2010). 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 (Etherington and Eggleston 2000).

After growth and maturation, females migrate to spawn in the high-salinity waters near the inlets (Whitaker 2006). Mature female blue crabs are more commonly found in higher salinity waters (>10 ppt) and males prefer lower salinities (3 to 15 ppt). Other studies have also shown the migratory behavior of mature female blue crabs continues between clutches, and spawning females are continually moving seaward through the spawning season (Hench et al. 2004; Forward et al. 2005; Darnell et al. 2009). Males do not migrate regularly as adults and are found predominantly in the rivers and on the western side of the sounds.

A tagging study conducted in North Carolina during 2002 through 2005 demonstrated that most mature female blue crabs were recaptured shortly after release near the release site (NCDMF 2008). However, dispersal was greater and long-distance returns were more prevalent in 2003 from the north to the south. Additionally, releases in the upper and mid-estuaries of the Albemarle-Pamlico systems and Cape Fear River show a general pattern of summer to fall movement towards the lower estuary areas and coastal inlets. This results in a general characterization of mature female movement seaward throughout the growing season.

Mature female blue crabs tagged in the southern coastal area (i.e., south of the Pamlico region) have a southward pattern of movement (NCDMF 2008). A similar trend was noted in mature female crabs released in the Atlantic Ocean south of the Cape Fear River during February to April 2005 and 2006 and suggested the warming of the estuarine waters was a cue to female blue crab movement (Logothetis et al. 2007). A significant portion of mature females in the southern area overwinter in the ocean near the coastal inlets and move back into the estuaries the following spring to forage and potentially spawn multiple times (NCDMF 2008).

1.2.3 Age & Size

Fischler (1965) reported an average life span of three years for blue crabs in North Carolina and a maximum size of around 217 mm. Estimates of maximum age have ranged between five and eight years for blue crabs in the Chesapeake Bay (Rugolo et al. 1997). Age determination of crustaceans is difficult because, unlike finfish, they lack permanent hard structures because crabs shed their hard parts through molting.

Biochemical measures for ageing blue crabs have been attempted on those in the Chesapeake Bay (Ju et al. 1999; Ju et al. 2001; Puckett et al. 2008) and Florida (Crowley 2012). Cellular oxidation products termed “lipofuscins” (LF) are used, which accumulate as stable fluorescent by-products in specific tissues of the blue crab. The amount of LF held in the tissues increases with age (Puckett et al. 2008). The level of LF was found to be positively correlated with chronological age of crabs raised in both the laboratory and in artificial ponds (Ju et al. 1999). However, a study in Florida, using two known age cohorts, found that lipofuscin indices were negatively correlated to age (Crowley 2012). These results suggest that more research is needed before this method can be used to age blue crabs.

Another method that has been used to determine age in crustaceans uses growth bands found around the calcified region of the eyestalk or gastric mill in shrimp, crabs, and lobsters (Kilada et al. 2012). 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.

1.2.4 Growth

Traditional growth models used for finfish are impractical to apply to crustaceans in general because the models assume growth is continuous (von Bertalanffy 1938; Schnute 1981). For blue crabs and other crustaceans, the shell grows in discrete stages via shedding of the exoskeleton (molt). However, the von Bertalanffy growth function returned similar results to crustacean-specific growth models that accounted for the unique growth characteristics of the blue crab (Eggleston et al. 2004; Johnson 2004). The similarity of the two growth models is likely due to the increasing time between molts that occurs as the crabs grow larger, mirroring the decreasing rate of growth with size evident in the von Bertalanffy growth function.

Carapace-width-to-length relationships have been estimated for blue crabs sampled from many estuaries throughout their range in the eastern United States. Murphy et al. (2007) used carapace width and body weight of blue crabs collected commercially from six locations in Florida. The carapace-width (mm)-to-weight (g) relationships for crabs collected in Florida (females: n = 2,254, males: n = 3,050) were:

Female: $W = 0.0000551 * CW^{1.8660}$; $r^2 = 0.620$

Male: $W = 0.0000397 * CW^{2.1430}$; $r^2 = 0.602$

Rothschild and Ault (1992) estimated a carapace-width-to-length relationship for blue crabs using 5,000 crabs collected in Chesapeake Bay. Their sex-specific carapace-width (mm)-to-weight (g) relations were:

Female: $W = 0.0034865 * CW^{2.1165}$

Male: $W = 0.00022105 * CW^{2.7208}$

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 15°C to 30°C, and growth stops when the temperature goes below 10°C (Cadman and Weinstein 1988). 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 (Bauer and Miller 2010). Laboratory observations indicate blue crabs grow 12% to 35% per molt (Cadman and Weinstein 1988). Most blue crabs go through 18 to 20 post-larval molts before becoming sexually mature (Van Engel 1958).

1.2.5 Reproduction

Blue crabs mature between one and two years of age in North Carolina (Johnson 2004). Mating occurs during the spring or summer in brackish estuarine waters as female blue crabs molt into maturity (Forward et al. 2003; Whitaker 2006). Males may mate after their third or fourth intermolt, females mate only once in their lives (Hill et al. 1989). The sperm from this mating is stored in seminal receptacles of the female and used as often as the female spawns during a one or two year period (Hill et al. 1989). All young produced by a female must be fertilized by stored sperm (Darnell et al. 2009). Spawning typically occurs within two months after mating if mating occurs early in the growing season; however, females can retain sperm through the winter for spawning the following spring (Hill et al. 1989; Forward et al. 2003).

Spawning is initiated after migration to high-salinity areas near oceanic inlets. In the Chesapeake Bay, Prager et al. (1990) found that fecundity was significantly related to carapace width and estimated the average fecundity was 3,200,000 eggs per clutch. Females may spawn once or several times a season. Spawning has two peak pulses, April–June and August–September, in North Carolina (Darnell et al. 2009).

For the current assessment, length at maturity (50% mature, L_{50}) for female blue crabs was determined by fitting a logistic model to the available maturity data. It was necessary to pool maturity data across multiple programs and areas to ensure sufficient sample sizes. Additionally, Otto et al. (1990, cited by Hjelset et al. 2009) recommended pooling data from different sampling methods to reduce bias in estimates of size at maturity. Maturity data collected by the NCDMF's Estuarine Trawl Survey (Program 120), Juvenile Anadromous Trawl Survey (Program 100), Pamlico Sound Survey (Program 195), and commercial fish house sampling (Program 436) were included in the model. Programs 100, 120, and 195 are described in more detail in section 2.2 of this report. Program 436 is described in more detail in section 2.1.1.3 of this report. Length at maturity was estimated by year for 1987 through 2015 to derive annual estimates of length at 50% maturity (L_{50}). Estimates of L_{50} ranges from 98.8 mm in 1999 to 125.7 mm in 2015 (Figure 1.1). Estimates were used to determine maturity of female recruits and fully recruited females in the assessment method (see section 3.2 of this report).

1.2.6 Mortality

The natural mortality rate (M) is a key parameter in stock assessments but often is one of the most uncertain. Johnson (2004) estimated natural mortality of blue crabs in North Carolina using Hoenig's method (1983), which relates M to the maximum age in the population. Assuming a maximum age of 5 years, Johnson (2004) estimated M to equal 0.87. This value of M was assumed in the 2004 stock assessment of North Carolina blue crabs (Eggleston et al. 2004).

Hewitt et al. (2007) estimated M for blue crabs in the Chesapeake Bay using a variety of methods and concluded that M values ranging between 0.7 and 1.1 per year were reasonable for that stock. Wong (2010) assumed $M = 0.80$ in the 2010 assessment of the Delaware Bay blue crab stock.

Total mortality (Z) is the sum of natural, fishing, and any other sources of mortality. Johnson (2004) and Eggleston et al. (2004) estimated Z using length-based methods based on data collected during June by NCDMF Program 195. The length-based Z estimates ranged from 0.91 to 1.22 between 1987 and 2003 and averaged 1.03 per year during that time period. Estimates of Z for blue crabs in the Chesapeake Bay in the 1990s ranged from 1.0 to 1.5 (Rugolo et al. 1997). Estimates of Z derived from the results of a catch-survey analysis applied to the Delaware Bay blue crab stock ranged from 0.50 to 2.69 and averaged 1.51 per year during 1978 to 2009 (Wong 2010).

Fishing mortality rates (F) can be estimated directly (e.g., tagging studies) or indirectly. The results of a catch-survey analysis applied to the North Carolina blue crab stock were used to derive estimates of F, which ranged from 0.13 to 2.03 between 1987 and 2003 when M was assumed equal to 0.87 (Eggleston et al. 2004; Johnson 2004). Wong (2010) applied a catch-survey analysis to the Delaware Bay blue crab stock and the results were used to estimate the upper bound of F (see reference for details). Estimates of the upper bound for F ranged between 0.22 and 1.74 during 1978 to 2009 and averaged 0.75 per year.

Fishing mortality rates are difficult to estimate, especially when losses to the fishery are unknown. For example, reporting of discards and bycatch is not always required; if these quantities are significant and associated mortality is high, estimating F is made increasingly difficult. For blue crabs, the mortality associated with shedding operations may be substantial, with estimated losses of 10 to 30% daily after the crabs are taken from the water but before they are sold as soft crabs (Chaves and Eggleston 2003).

1.2.7 Food & Feeding Habits

Blue crabs consume a wide variety of food, fulfilling roles as predators and detritivores. They are large consumers of annelids, polychaetes, crustaceans, live or dead fish, vegetation, detritus, and feed heavily on oyster spat and juvenile clams (Williams 1984). Bivalve mollusks are a major portion of blue crab diets (Hines et al. 1990; Laughlin 1982; Cordero and Seitz 2014). 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.

1.3 Habitat

1.3.1 Overview

The blue crab life cycle consists of an offshore phase and an estuarine phase. The offshore phase primarily consists of mature females that spawn in ocean waters, and planktonic larvae prior to migrating into the estuary. Blue crabs use a wide range of habitats based on life stage, sex, maturity, and associated salinity preferences, and occur across a broad spectrum of water quality parameters (Table 1.1). Wetlands, submerged aquatic vegetation (SAV), shell bottom, and unvegetated estuarine and ocean soft bottom are used by this species at various stages of their life cycle. The blue crab is common to all North Carolina coastal waters.

1.3.2 Spawning Habitat

Blue crabs spawn weeks after mating in late spring to early fall (Whitaker 2006). After mating, inseminated female blue crabs migrate from their usual brackish areas to high-salinity waters near ocean inlets. Females rely on high-salinity cues to ensure eggs are released for their development on the continental shelf. Ogburn and Habegger (2015) used SEAMAP data from 1990-2011 to assess spawning habitat in the South Atlantic Bight. Using reproductive condition of mature females as an indicator of spawning, they found that 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. The analysis indicated a South Atlantic regional decline in the number of offshore spawners, high inter-annual fluctuations in female crab density in Raleigh Bay, moderate but consistent densities in Onslow Bay, and low and declining densities in Long Bay. Results of this study and Ramach et al. (2009) suggest that inlets are serving more as migration corridors to the ocean where eggs are released and dispersed.

The first larval stage (zoeae) is carried offshore by ocean currents (Costlow and Bookhout 1959; Costlow et al. 1959; Epifanio 1995). Zoeae larvae are restricted to high salinity areas because of their intolerance of low salinity water (Costlow and Bookhout 1959). Their intolerance of low salinity water continues into the megalopal stages, when they return to the estuary.

1.3.3 Nursery & Juvenile Habitat

Once within the estuary, postlarvae (megalopae) settle in beds of submerged aquatic vegetation and other available complex habitats (i.e., salt marsh, detritus, and oyster shell) where they undergo further metamorphosis to become juveniles (Heck and Thoman 1981; Orth and van

Montfrans 1987; Hill et al. 1989; Ruiz et al. 1993; Pardieck et al. 1999; Posey et al. 1999; Etherington and Eggleston 2000).

Submerged aquatic vegetation is an important nursery habitat, particularly for early juveniles (<12 mm carapace width) that provide refuge from predators. In the Albemarle-Pamlico system, most initial recruitment of juvenile crabs occurs in SAV beds around inlets behind the Outer Banks, excepting major storm events. In years with large storm events, crabs disperse into lower salinity habitats (Etherington and Eggleston 2000). Studies have indicated that juvenile blue crabs occur in greater abundance in large or continuous SAV than in shallow unvegetated bottom or small patchy grass beds (Williams et al. 1990; Murphey and Fonseca 1995; Eggleston et al. 1998; Hovel 2003). Subtidal oyster reefs are also used as nursery habitat for early juveniles (Eggleston et al. 1998). After metamorphosis, juveniles undergo a secondary migration to shallow, less-saline waters in the upper estuaries and rivers or western Pamlico Sound (Etherington and Eggleston 2000). Ralph (2014), using a habitat-specific demographic model to quantify the effects of habitat on population fitness, found increased survival of age-0 crabs when vegetated habitats were present, which resulted in increased population growth rates. They concluded that since the vegetated habitats provided protection from fishing and predator mortality, the population could be subjected to higher fishing mortality rates and still maintain or increase population size.

Where SAV and subtidal oyster reefs are absent from estuaries in North Carolina and in the South Atlantic, lower salinity regions in the river-dominated estuaries provide important nursery areas for the blue crab population (Posey et al. 2005). Research in the Cape Fear and New rivers confirmed that marsh and shallow soft bottom in oligohaline and mesohaline portions of these rivers were important nursery areas with increased growth and reduced predation relative to the lower more saline portions of the rivers (Posey et al. 2005). The NCDMF estuarine trawl survey data show that blue crab is one of the dominant juvenile species in marshes and shallow tidal creeks (NCDMF unpub. data; Epperly and Ross 1986).

Wetlands, SAV, oyster reefs, and shallow soft bottom provide refuge and foraging area for juvenile crabs. Blue crabs forage heavily on oyster reefs, particularly oyster spat (Coen et al. 1999; Posey et al. 2004). Connectivity between these habitats provides a corridor for blue crabs to move through the estuary and enhances the ability to forage (Micheli and Peterson 1999; Grabowski et al. 2000).

1.3.4 Adult Habitat

Adult blue crabs use many of the same habitats as juveniles and are an important predator on submerged soft flats, marsh edge, and oyster reefs (NCDEQ 2016). Habitat partitioning by sex, maturity state, egg stage and salinity has been documented (Millikin and Williams 1984; Hines et al. 1987; Wolcott and Hines 1990; Ramach et al. 2009). General patterns include adult males and juvenile females being located further upstream and away from the waterbody mouth than females; juvenile females in shallower water than males and mature females in deeper water than juveniles and males; and females with late-stage eggs closer to the waterbody's mouth than females with early stage eggs. Egg bearing crabs migrate out of the estuary using ebb tide transport (Forward et al. 2003; Carr et al. 2004). Since females undergo a spawning migration and are observed migrating even when not gravid (Darnell et al. 2009), they are more likely to be found in higher-salinity waters near the oceanic inlets than in oligohaline areas.

1.3.5 Habitat Issues & Concerns

Portions of estuarine habitats used by various life stages of blue crab have been degraded or lost over time by a variety of anthropogenic sources (NCDEQ 2016). Dredge and fill activities, navigational dredging, shoreline stabilization, and erosion from boat wakes and natural sources have contributed to wetland loss. When assessing the effect of bulkheads and living shorelines on fish and invertebrates, Scyphers et al. (2011) found living shorelines to support a greater abundance and diversity of aquatic life, with blue crabs being the most clearly enhanced (300% more abundant). Land use changes, ditching and draining, and land disturbance lead to increased stormwater runoff, which can carry nutrients, sediment, toxins, and pathogens into surface waters. This, along with point source wastewater discharges and impacts from water based activities like marinas, can degrade water quality, resulting in loss of SAV, and water quality conditions that are stressful to blue crabs (e.g., low dissolved oxygen, increased susceptibility to disease, excessive nutrients, high organic loading, and chemical pollution). Sea level rise, subsidence, invasive species, and storms are also stressors that impact critical habitat. The effect of anthropogenic threats on SAV, wetlands, shell bottom, soft bottom, and water quality are summarized in the NC Coastal Habitat Protection Plan (NCDEQ 2016).

Although indirect, blue crabs are affected by natural disturbances of their environment. In particular, tropical cyclones can affect blue crab harvest in the short term by concentrating blue crabs in areas where they are vulnerable to fishing gear (Eggleston et al. 2004). These effects can have long-term effects as well. Since the relocation of individuals induces a change in localized abundance, harvest could be affected. Not all the effects of tropical cyclones are detrimental. For example, peaks in post-larval blue crab settlement coincided with tropical cyclone tracks that came from a southwesterly direction (Eggleston et al. 2010). The massive ingress of post-larval blue crabs could make a significant contribution to the blue crab population. The caveat is that storm forces must be moderate. Excessive freshwater input can alter the salinity of large bodies of water, increasing megalopae and juvenile blue crab mortality, and thereby negating the benefits of increased settlement.

Prevalence and lethality of diseases and parasites can increase under stressful conditions and potentially impact blue crab populations. For example, infection rates by the parasitic dinoflagellate *Hematodinium perezi* along the Atlantic and Gulf coasts can exceed 50% and is usually lethal (Butler et al. 2014). 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 (Rogers et al. 2015).

Endocrine disrupting chemicals that enter surface waters through point or nonpoint sources 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 (Booth and Zou 2016).

1.4 Description of Fisheries

1.4.1 Commercial Fishery

The blue crab resource supports North Carolina's most valuable commercial fishery. During 1950 through 2016, commercial landings of blue crabs have ranged from a low of 6.29 million pounds per year to a high of 67.1 million pounds per year (Figures 1.2 and 1.3). During the last decade (2007-2016), an average of 26.9 million pounds per year has been landed by the commercial fishery. The ex-vessel value of commercial blue crab landings was highest during 1994 through 2003, averaging 54.6 million dollars (2016 USD)[1] per year. Before 1994, the average ex-vessel value of North Carolina's commercial blue crab landings was 9.9 million dollars (2016 USD) per year (1950–1993 average). During 2004 through 2016, the ex-vessel value of commercial blue crab landings averaged 28.0 million dollars (2016 USD) per year.

Commercial fishermen have harvested blue crabs with a variety of different gears over time, including dredges, trotlines, pots, and trawls (Figure 1.2). The majority of blue crabs (83.5%) landed from 1950 to 2016 was harvested by pots. Pots have accounted for 98.5% of North Carolina's commercial blue crab landings during the last decade (2007-2016).

Peeler and soft crabs have been a relatively small portion of the commercial fishery for blue crabs, comprising 2.1% of the total blue crab landings reported from 1950 to 2016 (Figure 1.3). Peeler crabs are a value-added harvest that is captured via peeler pots and trawling for hard crabs and shrimp, mainly during the spring, as well as peeler trawls that target peeler crabs. The peelers are then held in shedding systems until they molt and are sold as soft crabs, either shipped live or cleaned and frozen. The peeler crab portion of the overall blue crab commercial fishery is small; however, the impact of the peeler crab fishery may be underestimated due to unreported mortality in shedding operations. Blue crabs placed in shedding operations are not reported until they are sold and thus any mortalities are not currently represented in the landings.

The commercial fishery for blue crab primarily occurs during late spring through the fall (Figure 1.4). Reported landings are highest in July and August, and this pattern has persisted for at least the last four decades.

The number of commercial fishermen that have reported landings of blue crabs and the associated number of trips have generally decreased from 1994 to 2016 (Table 1.2). The number of commercial fishermen that have reported landings of blue crabs has ranged between 884 and 2,287 during that time period. The number of trips in which blue crabs were landed in North Carolina ranged from a low of 51,707 to a high of 143,055 over the same period.

1.4.2 Recreational Fishery

Recreational fishermen in North Carolina harvest blue crabs with a variety of gears, including pots (collapsible and rigid), gill nets, trawls, hand lines, and dip nets. A separate license category, the Recreational Commercial Gear License (RCGL), allows recreational fishermen to use limited amounts of certain commercial gear to harvest seafood for personal consumption (see section 1.5.4.2, this report). Estimates of the RCGL blue crab harvest are available from NCDMF surveys conducted from 2002 to 2008. During 2002 through 2008, an estimated average of 26,402 RCGL recreational fishing trips per year was directed at blue crabs (Table 1.3). In that same time period, RCGL-licensed recreational fishermen harvested from 94.6 thousand pounds to 117 thousand pounds of blue crabs per year. In terms of number of blue crabs, recreational harvest by RCGL licensees has averaged 321 thousand blue crabs per year between 2002 and 2008. The amount of blue crabs discarded by recreational fishermen has been approximately half the recreational harvest during this time period. Total catch (including

[1] All values converted to 2016 U.S. dollars (USD) based on the annual average producer price index (PPI) values (U.S. Bureau of Labor Statistics, pers. comm.). The PPI is used to deflate revenue streams to measure real growth in output. The PPI tracks changes in manufacturer selling prices for consumer goods. For 1981-2016 the PPI for unprocessed shellfish was used, prior to 1981 the meat, poultry, and fish PPI was used to adjust values for inflation.

harvest and discards) during 2011-2016 is based on the Coastal Angling Program (CAP) recreational crabbing mail survey (see section 2.1.2, this report) was estimated ranging between 131,690-200,051 crabs annually (Table 1.4). The mortality of blue crabs discarded from the recreational fishery is unknown.

Individuals are allowed to fish one pot per person from privately owned land or a privately owned pier with no license. It is not known whether this unlicensed recreational fishery constitutes a significant proportion of total recreational fishery for blue crabs.

1.5 Fisheries Management

1.5.1 Management Authority

The NCDMF is responsible for the management of estuarine and marine resources occurring in all state coastal fishing waters extending to three miles offshore (Figure 1.5). There are no federal or interstate FMPs that apply specifically to the blue crab fishery in North Carolina.

1.5.2 Management Unit Definition

The management unit includes the blue crab and its fisheries in all of North Carolina's coastal fishing waters.

1.5.3 Regulatory History

In December 1998, the first FMP for blue crabs was approved for North Carolina (NCDMF 1998). The 1998 FMP maintained the previously established minimum size limit of 5 inches and a 10% tolerance per container for undersize blue crabs on commercial fishing vessels. Mature females, soft crabs, and peeler crabs were exempt from the minimum size limit. The original FMP also modified existing rules to clarify language on fishing in or near blue crab spawning sanctuaries and recommended use of a 4 or 4.5-inch mesh trawl in inland waters. These changes included limits on allowable blue crab landings as bycatch from the shrimp fishery (50 crabs per person and a 100 crab vessel limit for RCGL holders and the larger of 50% of combined catch or 300 pounds for commercial operations), prohibited the baiting of peeler pots with anything but live male crabs, and made it unlawful to possess white-line peeler crabs between June 1 and September 1.

The Blue Crab FMP was amended in 2004 (NCDMF 2004). The 2004 amendment adopted a spawning stock trigger and associated measures to protect the blue crab spawning stock (see section 1.5.4.3, this report). Management measures included implementing by proclamation a seasonal maximum size limit of 6.75 inches (5% tolerance) for mature female hard crabs and 5.25 inches for mature female peeler crabs from September 1 through April 30 when the spawning stock index is abnormally low. This maximum size limit was enacted in January of 2006 and remained in effect through April 2014. Compliance with the female seasonal maximum size limit was marginal and largely ineffective at protecting large mature females. Even when crabbers complied with the management measure by releasing large females, these females 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.

The Blue Crab FMP was amended again in 2013 (NCDMF 2013). The 2013 amendment removed the spawning stock trigger and its associated measures. The amendment incorporated the use of a traffic light stock assessment and an adaptive management plan for management of the blue crab stock. The traffic light is divided into three characteristics: 1) adult abundance, 2) recruit abundance, and 3) production. Each characteristic uses data from several division biological surveys and sampling programs to determine the relative abundance of adult and recruit blue crabs in the population and various production indictors for the stock each year. Under the adaptive management framework, the traffic light is updated annually and evaluated for management need. Moderate management measures (Table 1.5) will be implemented in the blue crab fishery if either the adult abundance or production characteristic of the traffic light are at or above the 50% red threshold for three consecutive years. Elevated management measures will be implemented if either the adult abundance or production characteristic of the traffic light are at or above the 75% red threshold for two of three consecutive years. The recruit abundance indicator, while not used to trigger management action, may be used to augment any management action taken if a trigger is activated. The three-year time period was chosen to prevent taking management action as a result of annual variability in the blue crab stock and instead base any management response on the observation of a short but continued declining trend in the population. The 2013 amendment also established the blue crab stock is considered overfished when the proportion of red in the production characteristic of the traffic light is greater than or equal to 75% red for three consecutive years.

In May 2016, a revision to the 2013 amendment was adopted in response to the moderate management trigger being met for the adult abundance characteristic of the traffic light (NCDMF 2016). This revision required one additional escape ring in crab pots and one of the three escape rings must be located within one full mesh of the corner of the pot and within one full mesh of the bottom of the apron/stairs (divider) of the upper chamber of the pot; eliminated the harvest of v-apron immature female hard crabs (excluding peeler crabs) and included v-apron immature female hard crabs in the culling tolerance; prohibited the harvest of dark sponge crabs (brown and black) from April 1 to April 30 each year and included dark sponge crabs in the culling tolerance; lowered the culling tolerance from 10 percent to 5 percent for all crabs, except mature females; and prohibited the harvest of crabs with dredges except incidental to lawful oyster dredging as outlined in North Carolina Marine Fisheries Commission (NCMFC) Rule 15A NCAC 03L .0203(a)(2).

1.5.4 Current Regulations

1.5.4.1 Commercial Fishery

The Standard Commercial Fishing License (SCFL) and Retired Standard Commercial Fishing License are annual licenses issued to commercial fishermen who harvest and sell fish, shrimp, or crab. The number of SCFL licenses is currently capped at 8,896. A Commercial Fishing Vessel Registration is also required for fishermen who use boats to harvest seafood.

There is no regulatory season for commercial harvesting of blue crabs with the exception of a restriction on crab dredge usage from January 1 to March 1 and a cleanup period for lost and abandoned pots between January 15 and February 7. For trawls, a 4-inch stretch mesh tailbag is required west of a line dividing Pamlico Sound down the middle and a 3-inch stretch mesh tailbag is required to the east of this line.

From March 1 to August 31, it is unlawful to use trawls, pots, and mechanical methods for oysters or clams or take blue crabs with the use of commercial fishing equipment from crab spawning sanctuaries (Figure 1.6). During the remainder of the year the director of the NCDMF may, by proclamation, close these areas and may impose any or all of the following restrictions:

number of days, areas, means and methods which may be employed in the taking, time period, and limit the quantity.

Prior to June 6, 2016

Commercial fishery regulations include a year-round carapace width minimum size limit of 5 inches for male and immature female hard blue crabs and a 10% tolerance for undersize blue crabs based on the number of blue crabs in any storage container on a vessel. Mature females, soft and peeler crabs, and male crabs for use as peeler bait are exempt from this size limit. If pots are used, they must contain two unobstructed escape rings no less than 2 5/16 inches in inside diameter and must be fished at least every five days. Peeler pots with a mesh size less than 1 ½ inches are exempt from the escape ring requirement. Targeted crab dredging is allowed from January 1 to March 1 in a northern area of Pamlico Sound adjacent to Oregon Inlet. Oyster dredges may also be used to harvest blue crabs but blue crabs cannot exceed 50% of the total weight of the oyster and crab catch or 500 pounds, whichever is less.

June 6, 2016–Present

Commercial fishery regulations include a year-round carapace width minimum size limit of 5 inches for male hard blue crabs, no size limit for mature female blue crabs, no possession of immature female blue crabs (excluding peeler crabs), and no possession of dark sponge crabs (brown and black) from April 1 through April 30. Soft and peeler crabs, and male crabs for use as peeler bait are exempt from this size limit. A 5% tolerance for immature female, dark sponge crabs, and undersize male blue crabs based on number in any storage container on a vessel. Peeler pots with a mesh size less than 1 ½ inches are exempt from the escape ring requirement. The harvest of blue crabs with dredges is prohibited except incidental to lawful oyster dredging.

January 15, 2017–Present

Pots used to harvest blue crabs must contain three unobstructed escape rings no less than 2 5/16 inches in inside diameter and one escape ring must be located within one full mesh of the corner of the pot and within one full mesh of the bottom of the apron/stairs (divider) of the upper chamber of the pot.

Detailed information regarding North Carolina's current commercial fishery regulations is available on the NCDMF website (http://portal.ncdenr.org/web/mf/home).

1.5.4.2 Recreational Fishery

Prior to 1999, no recreational fishing license was required unless a vessel was used. After July 1, 1999, the RCGL was required when using certain allowable commercial gear. No license is required for the following non-commercial equipment: collapsible crab traps, cast nets, dip nets, and seines less than 30 feet. A RCGL is required to use commercial gear to harvest finfish and crustaceans for personal consumption. Recreational crabbers are prohibited by law from selling their catch, even if in possession of a RCGL. With a RCGL, a maximum of five pots of any type (peeler pots are disallowed) is allowed and must be fished at least every five days; pots cannot be fished at night. Pots must be removed from the water during January 15 through February 7. One pot per person may be used without a RCGL to fish from privately owned land or a privately owned pier with no license. The recreational fishery is not subject to reporting requirements. The current possession limit for the recreational fishery is 50 blue crabs per person per day not to exceed 100 blue crabs per vessel per day.

Prior to June 6, 2016

Recreational fishery regulations include a year-round carapace width minimum size limit of 5 inches for male and immature female hard blue crabs and a 10% tolerance for undersize blue crabs based on the number of blue crabs in any storage container on a vessel. Mature females, soft and peeler crabs are exempt from this size limit. If pots are used, they must contain two unobstructed escape rings no less than 2 5/16-inches in inside diameter.

June 6, 2016–Present

Recreational fishery regulations include a year-round carapace width minimum size limit of 5 inches for male hard blue crabs, no size limit for mature female blue crabs, no possession of immature female blue crabs (excluding peeler crabs), and no possession of dark sponge crabs (brown and black) from April 1 through April 30. A 5% tolerance for immature female, dark sponge crabs, and undersize male blue crabs based on number in any storage container on a vessel.

January 15, 2017–Present

Pots used to harvest blue crabs must contain three unobstructed escape rings no less than 2 5/16-inches in inside diameter and one escape ring must be located within one full mesh of the corner of the pot and within one full mesh of the bottom of the apron/stairs (divider) of the upper chamber of the pot.

Detailed information regarding North Carolina's current recreational fishery regulations is available on the NCDMF website (http://portal.ncdenr.org/web/mf/home).

1.5.4.3 Spawning Stock Trigger

In addition to the regulations described above, the 2004 amendment to the Blue Crab FMP adopted a spawning stock trigger to protect the blue crab spawning stock (NCDMF 2004). A spawning stock index derived from September data collected by the NCDMF Pamlico Sound Survey (Program 195; see section 2.2.3, this report) is evaluated annually to determine whether the trigger has been activated (Figure 1.7). The spawning stock index is calculated as the sum of the carapace widths of mature female blue crabs divided by the total number of tows. The trigger is activated when the spawning stock index falls below the lower 90% confidence limit of the reference baseline average for two consecutive years. In the 2004 amendment, the reference baseline was 1987 through 2003. The amendment states that the reference baseline will be updated every five years as part of the FMP review. However, if the trigger is active at the time of the review, the reference baseline update will be delayed until the trigger is no longer active.

When the trigger is activated, the NCDMF has the proclamation authority to implement spawning stock protection measures. These measures include a 6 ¾-inch maximum size limit on mature female blue crabs and a 5 ¼-inch maximum size limit on female peeler crabs from September through April for all fisheries in order to protect mature female crabs during their spawning migration. In addition, the culling tolerance of blue crabs in any container on a vessel in the commercial fishery will be lowered from 10% by number to 5% by number.

The spawning stock trigger was activated every year from 2006 through 2013 (repealed effective in 2014; NCDMF 2013), and the associated measures were implemented.

1.5.5 Management Performance

The decline of commercial blue crab landings continued after the adoption of the Blue Crab FMP in 1998 (Figures 1.2 and 1.3). Based on data collected from the NCDMF Trip Ticket Program (see section 2.2.1, this report), commercial landings of blue crabs during 1994 through 1997 averaged 55.8 million pounds per year. During 1998 through 2016, commercial fishermen landed an average of 33.4 million pounds of blue crabs per year. The decrease in commercial landings is due, at least partly, to the shutting down of crab processing plants, which reduced the amount of crabs that seafood dealers could move, thereby reducing demand and ultimately reducing harvest. It is not certain how much of the decline in landings is attributable to the FMP. Changes in stock size may also be a factor in the decline. Other potential contributing factors could include changes in effort and environmental variability.

1.6 Assessment History

1.6.1 Review of Previous Methods & Results

The last benchmark assessment of blue crab in North Carolina waters for management purposes was performed by NCDMF in 2011. The assessment applied the Traffic Light approach to evaluate stock status. The previous assessment recommended defining the overfished condition based on the blue crab production Traffic Light such that when the proportion of red for the production Traffic Light is greater than or equal to the third quartile (>=0.75) for three consecutive years, the blue crab stock is considered overfished. Based on this definition, the results of the previous assessment suggested the North Carolina blue crab stock was not overfished. An overfishing definition and status relative to overfishing could not be determined because available data were considered insufficient for estimating reliable fishing mortality rates. Therefore, the previous assessment considered the status of the North Carolina blue crab stock relative to overfishing as unknown. Details of the Traffic Light approach are provided in Appendix A.

1.6.2 Previous Research Recommendations

Research recommendations identified from the 2011 stock assessment (NCDMF 2011) focused on the lack of sufficient data to apply a traditional method to assess the status of the blue crab stock as identified in Amendment 1 (NCDMF 2004). To address this deficiency, the following recommendations for research and monitoring were offered (no particular order):

- Continue existing programs that have been used to monitor North Carolina's blue crab stock to maintain baseline data
- Identify key environmental factors that significantly impact North Carolina's blue crab stock and investigate assessment methods that can account for these environmental factors
- Conduct a study of the selectivity of the gear used in the Juvenile Anadromous Trawl Survey (Program 100) to evaluate the size at which blue crabs are fully-selected to the survey gear; the results of such a study could help determine whether the survey data could be used to develop a reliable index of blue crab recruitment for the Albemarle region; no such index is currently available
- Expand spatial coverage of the Estuarine Trawl Survey (Program 120) to include shallow-water habitat in Albemarle Sound; sampling in shallow-water habitat is intended to target juvenile blue crabs so that a recruitment index for the Albemarle Sound could be developed

- Expand temporal coverage of the Estuarine Trawl Survey (Program 120) beyond May and June sampling; additional sampling later in the blue crab's growing season would provide more information on within-year changes in growth, mortality, and abundance; at a minimum, recommend addition of September sampling in order to capture the fall settlement peak
- Expand spatial coverage of Pamlico Sound Survey (Program 195) to include deepwater habitat in Albemarle Sound and the Southern Region; expanding the sampling region of adult blue crab habitat would allow for a more spatially-comprehensive adult index; additionally, there would be increased confidence in comparison of adult abundance trends among regions since all would derive from the same sampling methodology
- Implement a statewide survey with the primary goal of monitoring the abundance of blue crabs in the entire state; such a survey would need to be stratified by water depth to ensure capture of all stages of the blue crabs' life cycle and standardized among North Carolina waters
- Implementing monitoring of megalopal settlement near the ocean inlets could potentially add a predictive function to the blue crab stock assessments in the future; Forward et al. (2004) detected a positive, linear relationship between megalopal abundance and commercial landings of hard blue crabs for both the local estuarine area and the entire state of North Carolina when a two-year time lag was implemented (Forward et al. 2004); such monitoring is critical to track larval ingress peaks and the effect of natural forces, such as tropical storms and prevailing winds, on ingress.
- Continue surveys of recreational harvest and effort to improve characterization of the recreational fishery for blue crabs
- Identify programs outside the NCDMF that collect data of potential use to the stock assessment of North Carolina's blue crabs
- Perform in-depth analysis of available data; consider standardization techniques to account for year and other effects in development of indices; explore utility of spatial analysis in assessing the blue crab stock.

2 DATA

2.1 Fisheries-Dependent

2.1.1 Commercial Fishery Monitoring

Prior to 1978, North Carolina's commercial landings data were collected by the National Marine Fisheries Service (NMFS). In 1978, the NCDMF entered into a cooperative program with the NMFS to maintain and expand the monthly surveys of North Carolina's major commercial seafood dealers. Beginning in 1994, the NCDMF instituted a trip-ticket system to track commercial landings.

2.1.1.1 Survey Design & Methods

On January 1, 1994, the NCDMF initiated a Trip Ticket Program (TTP) to obtain more complete and accurate trip-level commercial landings statistics (Lupton and Phalen 1996). Trip ticket forms are used by state-licensed fish dealers to document all transfers of fish sold from coastal waters from the fishermen to the dealer. The data reported on these forms include transaction date, area fished, gear used, and landed species as well as fishermen and dealer information.

The majority of trips reported to the NCDMF TTP only record one gear per trip; however, as many as three gears can be reported on a trip ticket and are entered by the program's data clerks in no particular order. When multiple gears are listed on a trip ticket, the first gear may not be the gear used to catch a specific species if multiple species were listed on the same ticket but caught with different gears. In 2004, electronic reporting of trip tickets became available to commercial dealers and made it possible to associate a specific gear for each species reported. This increased the accuracy of reporting by documenting the correct relationship between gear and species. In 2004, electronic reporting of trip tickets became available to all dealers who chose to use it. In 2013, a NCMFC rule was implemented making it mandatory to report electronically if a seafood dealer averaged 50,000 pounds of finfish over the most recent three-year period. Many federal dealers were already required to report electronically to NMFS and used the NC Trip Ticket Software Program to meet their reporting requirements for NMFS and NC.

2.1.1.2 Sampling Intensity

North Carolina dealers are required to record the transaction at the time of the transactions and report trip-level data to NCDMF on a monthly basis.

2.1.1.3 Biological Sampling

Program 436 (P436) was initiated in April 1995 to collect fisheries-dependent data at fish houses from North Carolina's commercial blue crab fishery. The program aimed to determine size, sex, and maturity (female) for blue crabs and length/weight of non-blue crab species harvested in the commercial crab fisheries and obtain information from the commercial harvester on harvest location, soak time, weight of catch (Trip Ticket information), and specifications on gear type and amount. Initially, sampling was limited to the northeast and Pamlico Sound regions of North Carolina. Statewide sampling was initiated in 1998. Subsamples of sorted (by market category) and unsorted catches are taken and biological information is recorded. All blue crabs in a subsample are measured and sexed, and maturity of females is recorded. Program 436 only samples voluntarily cooperative fish houses, and sampling distribution may not reflect landing patterns.

2.1.1.4 Biases

Because trip tickets are only submitted when fish are transferred from fishermen to dealers, records of unsuccessful fishing trips are not available. As such, there is no direct information regarding trips where a species was targeted but not caught. Information on these unsuccessful trips is necessary for calculating a reliable index of relative abundance for use in stock assessments.

Another potential bias relates to the reporting of multiple gears on a single trip ticket. This bias is considered minimal for blue crab landings because the commercial blue crab fishery uses gears specific to crabbing (e.g., crab pots, crab trawls, trotlines). Therefore, it is often possible to identify the gear used to catch blue crabs on a trip ticket that lists multiple gears and species.

2.1.1.5 Development of Estimates

All trips landing blue crab from 1994 to 2016 were subset from the trip ticket database. This subset contains 51,305,547 observations and 48 variables including species other than blue crab caught on each trip. Blue crab landings are divided into hard blue crabs, peeler blue crabs, and soft blue crabs. Each type of blue crab is recorded with its own unique species code. Therefore, landings can be split between hard, peeler, and soft blue crabs as opposed to years prior to 1994.

The length-frequency distribution of blue crabs in North Carolina's commercial landings was calculated using biological sampling data from P436. The length-frequency distributions were computed by year for 1995 to 2016.

2.1.1.6 Estimates

The landings of blue crab have generally declined overall since 1994. However, in recent years, the landings have started to show an increasing trend (Figures 1.2 and 1.3). Also, the majority of landings occur from two areas, the Pamlico Area (51%) and Albemarle Area (44%). Historically, the majority of the blue crab landings came from the Pamlico Area, but in more recent years, the Albemarle Area has been the top producer (Figures 2.1). The majority of hard blue crabs occurred during the summer months while peeler and soft crabs were primarily landed during spring months (Figure 2.2).

The modal peak of hard crabs is 140 mm CW bin with the majority of crabs in the 130 through 150 mm CW bins (Figure 2.3). Peeler crabs have a modal peak in the 110 mm CW bin with the majority of crabs in the 90 through 120 mm CW bins.

The commercial catch data during 1995-2016 were further partitioned by sex and stage (<127 mm CW as recruits and ≥127 mm CW as fully recruited crabs; Figure 2.4) for assessment model input based on the biological sampling from P436. See Section 3 of this report for assessment model input.

2.1.2 Recreational Fishery Monitoring

2.1.2.1 Survey Design & Methods

During 2001 through 2002, a telephone survey of RCGL holders was conducted to determine the 2001 recreational harvest of blue crabs (Nobles et al. 2002). Phone surveys of 388 RCGL holders were conducted between September 2001 and March 2002 to determine use of the RCGL, type of equipment, location of harvest, number of days harvesting, and daily and seasonal harvest estimates.

A mail survey of coastal and estuarine landowners was conducted in North Carolina between May 1, 2002 and April 30, 2003 (Vogelsong et al. 2003). The survey requested information on property characteristics, crabbing effort, and harvest. A total of 382 surveys were returned.

The NCDMF conducted monthly surveys of RCGL holders from 2002 to 2008 to collect information on recreational fishing. Participants were randomly selected and were asked about the number of trips taken and the type and number of gears used during the survey month. Participants were also asked to provide estimates for the numbers and pounds of each species caught and retained as well as the numbers of each species discarded.

From 2007 to 2010, the NCDMF surveyed approximately 20% of Coastal Recreational Fishing License (CRFL) holders regarding their participation in saltwater fishing activities including gigging, use of a cast net, shellfish collection, and crabbing.

Since 2010 through present, the NCDMF the Costal Angling Program (CAP) evaluates recreational crabbing with a mail survey. The CAP survey aims to collect data for estimating the participation in recreational crabbing among CRFL and grandfathered license holders, the number of trips taken and the amount of catch including harvest and discards. Descriptive characteristics of crabbing trips including: duration, party size, methods of harvest, county, waterbody, and access locations are also collected during this survey. Individuals are randomly selected and stratified by a combination of region of residence and license duration. The survey was conducted every two months.

2.1.2.2 Biological Sampling

There are currently no programs that collect biological samples of blue crabs from North Carolina's recreational fishery.

2.1.2.3 Biases

The Nobles et al. (2002) survey and NCDMF survey of RCGL holders were limited to fishermen in possession of a RCGL, thereby omitting non-licensed recreational fishermen that harvested blue crabs. The NCDMF survey of CRFL holders also omitted non-licensed recreational fishermen that harvested blue crabs. Estimates of recreational harvest by non-licensed fishermen are unknown. While initiating an estuarine landowner survey filled some of this gap, including many recreational crabbers who are exempt from RCGL and CRFL licensing, it does not take into account harvest from renters or that of fishermen legally harvesting blue crabs without a license.

2.1.2.4 Development of Estimates

In the CAP program, the number of potential participants is a product of the number of valid recreational licenses for the survey period and the percent of those who answered affirmatively to a crabbing participation question at the time of license purchase (or while updating contact information). The ineligibility rate is the number of anglers reporting they do not participate in crabbing divided by the total number of responses received. The estimated participation is a product of the number of potential participants and one minus the ineligibility rate. The mean number of trips per license holder is calculated by dividing the sum of all trips reported by all respondents by the number of respondents. Estimated effort is the product of the estimated number of potential crabbers participating and the mean trip per license holder. Catch is the number of a species harvested by each angler expanded to represent the population of license holders. The mean number of crabs caught per license holder is calculated by dividing the sum of crabs reported by all respondents by the number of respondents. Estimated catch is the product of the estimated number of potential crabbers participating and the mean number of crabs harvested per crabber.

2.1.2.5 Estimates

Fifty percent of all blue crabs were harvested along the Intracoastal Waterway, between Pamlico Sound and the Cape Fear River (Nobles et al. 2002). The total estimated blue crab harvest from RCGL holders in 2001 was 118,051 pounds. In this survey, 23.5% of the surveyed RCGL holders indicated that they targeted blue crabs.

The NCDMF survey of RCGL holders estimated that RCGL licensees took an average of 26,402 blue crab directed trips per year between 2002 and 2008 (Table 1.3). During this time period, RCGL holders harvested an average of 116,797 pounds per year, which amounted to 20% of the total estimated RCGL harvest.

Estimated blue crab harvest by RCGL holders was less than 0.40% of total blue crab commercial landings for 2001 through 2008. While the harvest of exempted shore- and pier-based pots and other non-commercial gear are unknown, it is unlikely that recreational harvest of blue crabs is significant in North Carolina.

The CAP survey estimated 44% of trips from central coastal area (Figure 2.5). Majority of the trips were contributed by Carteret (19%), Dare (21%), and Brunswick (17%) counties. Total catch (harvest + discards) ranged between 131,690 and 200,051 crabs annually (Table 1.4). Total effort and catch were concentrated during the summer and fall with a marked increase in trips being observed between May and October.

Recreational catch was not included in this assessment because the recreational catch of blue crab in North Carolina accounts for less than 0.4% of its commercial catch and no detailed information regarding recreational catch is available throughout the assessment time period.

2.2 Fisheries-Independent

2.2.1 Estuarine Trawl Survey (Program 120)

2.2.1.1 Survey Design & Methods

In 1971, the NCDMF initiated a statewide Estuarine Trawl Survey, also known as Program 120 (P120). The objectives of the program are to: 1) identify primary nursery areas and other critical habitats, 2) provide a long-term data base of annual juvenile recruitment for economically important species, and 3) provide a database for evaluation/permit comment on projects with potential environmental impact.

The survey samples shallow-water areas south of the Albemarle Sound system (Figure 2.6). Major gear changes and standardization in sampling occurred in 1978 and 1989. In 1978 tow times were set at one minute during the daylight hours. In 1989 an analysis was conducted to determine a more efficient sampling time frame to produce juvenile abundance indices with acceptable precision levels for the target species. A set of 104 core stations was identified, sampling would be conducted in May and June only, except for July sampling for weakfish (dropped in 1998, program 195 deemed adequate), and only the 10.5 ft. head rope trawl would be used. July sampling for a subset of the cores was reinstituted in 2004 in order to produce a better index for spotted seatrout.

The current gear is a 3.2-m otter trawl with 6.4-mm bar mesh body netting of 210/6 size twine and a tailbag mesh of 3.2-mm Delta-style knotless nylon with a 150-mesh circumference and 450-mesh length. The gear is towed for one minute during daylight hours during similar tidal stages and covers 75 yards.

All species taken are sorted, identified, and a total number is recorded for each species. For target species, a subset of at least 30-60 individuals is measured. Environmental data are recorded, including temperature, salinity, dissolved oxygen, wind speed, and direction. Additional habitat fields were added in 2008.

2.2.1.2 Sampling Intensity

Prior to 1989, sampling was year-round. From 1989 to 2003, a set of 104 fixed core stations was identified and sampling was conducted in May and June only. Since 2004, additional July sampling of a subset of the core stations has been conducted.

2.2.1.3 Biological Sampling

All blue crabs caught are counted. The catch of blue crabs is subsampled if there are more than 30 individuals that are less than 20 mm carapace width (CW). These crabs (<20 mm CW) are measured but not sexed. Larger blue crabs (>=20 mm CW) are sexed and measured.

2.2.1.4 Biases

Mature female blue crabs are present throughout the coastal waterways of North Carolina. When it is time to spawn, mature females migrate to the oceanic inlets near the barrier islands. Depending on the timing of sampling, the migration could artificially inflate the perceived abundance of mature females in Pamlico Sound by including transient, not resident, mature female crabs. Adult blue crabs more commonly occupy deeper water (<2 m) and are therefore less likely to be encountered by the gear in the locations sampled by Program 120.

2.2.1.5 Development of Estimates

Overall, a total of 7,779 samples captured 55,894 blue crabs from 1971 to 2016 (Table 2.1). The number of samples per year from core stations ranged from a low of zero (1972) to a high of 209 (1988). The number of blue crabs caught annually ranged from 18 to 2,794. The modal peak for blue crabs captured was 10 mm CW, with approximately 65% of blue crabs being less than 50 mm CW (Figure 2.7). The CW for blue crab ranged from 3 to 266 mm. The mean annual CW varied little throughout the time series, hovering around 50 mm.

Examination of the available data lead to the decision to develop sex-specific indices of relative abundance for blue crab recruits (crabs less than 127 mm CW). To generate these sex-specific indices, when individual sex information was unavailable the overall male:female sex ratio (60:40) was applied to the unsexed portions of the catch.

The nominal annual CPUE for both male and female recruits shows inter-annual variability with an overall declining trend through the time series (Figure 2.8). Male recruit CPUE ranged from a high of 7.9 in 1996 to a low of 1.6 in 2016. Female recruit CPUE ranged from a high 5.2 in 1996 to a low of 1.1 in 2016.

The standardized indices were input to the assessment models. A generalized linear model (GLM) framework was used to develop the standardized indices. Both Poisson and negative binomial error distributions were considered and the selected distribution was based on the estimate of dispersion (ratio of variance to the mean; Zuur et al. 2009). The Poisson distribution assumes equi-dispersion—that is, the variance is equal to the mean. Count data are more often characterized by a variance larger than the mean, known as overdispersion. Some causes of overdispersion include missing covariates, missing interactions, outliers, modeling non-linear effects as linear, ignoring hierarchical data structure, ignoring temporal or spatial correlation, excessive number of zeros, and noisy data (Zuur et al. 2009, 2012). A less common situation is underdispersion in which the variance is less than the mean. Underdispersion may be due to the model fitting several outliers too well or inclusion of too many covariates or interactions (Zuur et al. 2009). Data were first fit with a standard Poisson GLM and the degree of dispersion was then evaluated. If over- or underdispersion was detected, an attempt was made to identify and eliminate the cause of the over- or underdispersion (to the extent allowed by the data) before considering alternative models, as suggested by Zuur et al. (2012). In the case of overdispersion, a negative binomial distribution can be used as it allows for overdispersion relative to the Poisson distribution. Alternatively, one can use a quasi-GLM model to correct the standard errors for overdispersion. If the overdispersion results from an excessive number of zeros (more than expected for a Poisson or negative binomial), then a model designed to account for these excess zeros (e.g., zero-inflated model) can be applied.

Potential covariates were evaluated for collinearity by calculating variance inflation factors, applying a correlation analysis, or both. Collinearity exists when there is correlation between covariates and its presence causes inflated *P*-values.

Covariate selection started with a null model including only the intercept. The significant covariates were identified and added to the null model through a forward selection procedure based on Akaike Information Criterion (AIC, Akaike, 1974; Burnham and Anderson, 2002). At each step, the covariate that most greatly reduced the AIC value was added to the null model, and this process was repeated until inclusion of an additional covariate would not substantially improve model performance (i.e. the decrease in AIC was less than five).

2.2.1.6 Estimates

The GLM frequently selected depth, salinity, sediment size (i.e., hard rock, hard sand, soft mud, hard mud, clay, silt, muddy sand, sandy mud, sand and mud) and bottom composition (i.e., shell, grass, algae and detritus) as significant covariates for both male and female recruit abundance indices. The standardized CPUE for both male and female recruits varied annually with relatively low recruits in last three years, especially in 2016 (Figure 2.9).

2.2.2 Juvenile Anadromous Trawl Survey (Program 100)

2.2.2.1 Survey Design & Methods

The NCDMF Juvenile Anadromous Trawl Survey, also known as Program 100 (P100), was initiated in 1982 to determine relative abundance, growth, and distribution of juvenile alosine fishes and striped bass in Albemarle Sound (Figure 2.10). Since its inception, the survey has sampled seven stations (Hassler stations) in western Albemarle Sound. In July 1984, twelve sampling stations were added in the central Albemarle Sound area (Central Sound stations) to monitor juvenile striped bass abundance and to determine if a shift in the striped bass nursery area had occurred.

The program surveys a total of 62 fixed trawl sites, of which 19 are considered core sites. Continuous time series are available for Hassler and Central Sound trawls. Historic trawls were introduced to the program in 2004.

The survey uses an 18-foot semi-balloon trawl with a body mesh size of 0.75 inch and a 0.25-mesh tailbag. A 10 or 15-minute tow pulled at 2.4 knots with the balloon trawl constitutes one unit of effort. Hassler trawls are pulled for 15 minutes while all others are 10 minute tows. Water quality and habitat information such as temperature, salinity, and dissolved oxygen are recorded. In 2004, forty-three stations were reactivated. Not all sampling was conducted in 2005 due to a gas shortage. In 2010 blue crab sex became a mandatory field and maturity and sponge stage fields were added.

2.2.2.2 Sampling Intensity

Program 100 trawls are conducted June through October, except Hassler and Central Sound trawls are conducted bimonthly from July through October. Due to difference in sampling and lack of blue crab catch in June, only July through October were used in this analysis.

2.2.2.3 Biological Sampling

The catch of each tow is sorted by species, counted, and measured. The carapace width, sex, and maturity (if female) are recorded for blue crabs. Subsampling methods are used if the catch of blue crabs is excessive.

2.2.2.4 Biases

The Program 100 survey samples only a couple of deep-water areas in Albemarle Sound, and the sampling does not include many of the tributaries or parts of the sound east of the Alligator River. This gap in sampling potentially omits mature females on their spawning migration to the oceanic inlets. Also, the survey trawl cannot sample in shallow waters in Albemarle Sound because of the complex structure, primarily stumps, associated with the shoreline. This potentially omits capture of juvenile blue crabs using the complex, shallow-water habitat as refuge from predators.

2.2.2.5 Development of Estimates

Data was analyzed for July through October. Core stations (Hassler and Central Sound trawls) were used for the analysis as they represent stations that were sampled continuously throughout the assessment period. CPUE was evaluated with effort being equal to one tow.

Overall, a total of 5,163 samples captured 27,453 blue crabs from 1972 to 2016 (Table 2.2). The number of samples per year from core stations ranged from a low of 12 (1972) to a high of 162 (1987). The number of blue crabs caught annually ranged from 3 to 3,593. There are modal peaks for blue crabs captured at 110 and 150 mm CW (Figure 2.11). The CW for blue crab ranged from 2 to 210 mm. The mean annual CW varied throughout the time series, averaging around 115 mm.

Examination of the available data lead to the decision to develop seasonal sex-specific indices of relative abundance for fully recruited blue crabs (crabs greater or equal to 127 mm CW). The summer season is July-August and the fall season is September-October. To generate these seasonal sex-specific indices, when individual sex information was unavailable the overall male:female sex ratio (63.5:36.5) was applied to the unsexed portions of the catch.

The annual summer CPUE for both male and female fully recruited blue crabs shows inter-annual variability with an increasing trend in recent years (Figure 2.12). Male fully recruited summer CPUE ranged from a high of 6.0 in 2008 to a low of 0.01 in 1997. Female fully recruited summer CPUE ranged from a high 2.3 in 2009 to a low of zero in 1997. The annual fall CPUE for both male and female fully recruited blue crabs were lower in the earlier years of the time series and have been more variable since 2008. Male fully recruited fall CPUE ranged from a high of 15.0 in 2008 to a low of 0.03 in 1997. Female fully recruited fall CPUE ranged from a high of 10.5 in 2008 to a low of 0.04 in 1997.

The abundance indices were standardized for assessment model input. See Section 2.2.1.5 for CPUE standardization procedure.

2.2.2.6 Estimates

The GLM model frequently selected salinity and dissolved oxygen as significant covariates for explaining annual variation in fully recruited crab abundance indices. The standardized indices from P100 increased since 2007 for both male and female fully recruited crabs (Figure 2.13).

2.2.3 Pamlico Sound Survey (Program 195)

2.2.3.1 Survey Design & Methods

The Pamlico Sound Survey, also known as Program 195 (P195), was instituted in March 1987 to provide a long-term, fishery-independent database for important recreational and commercial fish species in the Pamlico Sound, and the lower Neuse, and Pamlico rivers (Figure 2.14). Data collected from the survey have been used to calculate juvenile abundance indices and estimate population parameters for interstate and statewide stock assessments of recreationally and commercially important fish stocks.

This is a stratified-random survey. Fifty-two to fifty-four randomly selected stations are trawled each sampling event for a minimum of 104 stations trawled each year. Initially stations were allocated in proportion to the size of the strata (Table 2.3). The number of stations per strata was determined by the following formula:

$$N_S = N_T*(F_S / F_T)$$

Where N_S = number of hauls per stratum
N_T = total number of hauls
F_S = area of stratums
F_T = total survey area

Currently randomly drawn stations are optimally allocated among the strata based upon all the previous sampling in order to provide the most accurate abundance estimates (PSE <20) for selected species (BDB program NCEFF42S). A minimum of three stations (replicates) are maintained in each stratum, and 5 stations each are set for the Neuse and Pamlico rivers and 3 stations for the Pungo River.

Sampling is conducted aboard the RV *Carolina Coast*, equipped with double-rigged demersal mongoose trawls. The RV *Carolina Coast* is a 44-ft fiberglass hulled double-rigged trawler. The trawl consists of a body made of #9 twine with 1.875-in (47.6-mm) stretch mesh. The codend of the net is constructed of #30 twine with 1.5-in (38.1-mm) stretch mesh. The tailbag is 80 meshes around and 80 meshes long (approximately 10-ft). A 120-ft (36.58-m) three-lead bridle is attached to each of a pair of wooden doors that measure 4 ft by 2 ft (1.22-m X .061-m) and to a tongue centered on the headrope. A 60-cm “poly-ball” is attached between the end of the tongue and the tongue bridle cable. A 0.1875-in (4.76-mm) tickler chain that is 3.0-ft (0.9.-m) shorter than the 34-ft (10.36-m) footrope is connected to the door next to the footrope. A bib or tongue of webbing is built into the center of the top body panel. This tongue extends forward from the point that would be the headrope location on a flat, balloon, or semi-balloon trawl. Use of a large float at the point of the tongue where it is attached to a center bridle allows the tongue to fish higher in the water column. The tongue helps to reduce escapement over the top of the trawl. Tow duration is 20 minutes at 2.5 knots.

Environmental and habitat data are recorded during the haul back of each trawl. Parameters measured include: weather description, light phase, surface and bottom temperature (°C), surface and bottom salinity (ppt), surface and bottom dissolved oxygen (DO)(mg/L), start time, secchi depth (cm; added 2008), sediment size, wind speed (knots), wind direction, precipitation, start and end latitude, and start and end longitude.

The entire catch is sorted by species; each species is enumerated and a total weight is taken for each species. Individuals of each target species are measured. If present in large numbers, a sub-sample of 30-60 individuals of each target species is measured and a total weight of the measured individuals for each species is taken. If not on the target species list, the species is enumerated and a total weight taken. Blue crab are on the target species list and measured to the nearest millimeter carapace width and an aggregate weight of all individuals is taken to the nearest 0.1 kg.

2.2.3.2 Sampling Intensity

Currently, sampling occurs annually during the months of June and September, typically during the middle two weeks of each month. Sampling has undergone some changes. From 1987 to 1989 sampling occurred in eastern Albemarle Sound. From 1987 to March 1989, sampling occurred in March and December (in addition to June and September). The Pungo River was added to the survey area in 1990.

There were six years where the survey did not occur over the same time series; 1988, 1999, 2003, 2009, 2012, and 2013. In 1988, the December leg of the cruise was partially extended into January 1989 because of scheduling conflicts and adverse weather conditions. In 1999, samples were collected during the month of July and the end of September and beginning of October because vessel repairs and hurricanes prevented following the normal schedule. In September 2003, hurricane Isabel caused a delay and sampling was completed two days into October. In September 2009, vessel repairs caused a delay and sampling was completed during the first week of October. In June 2012, vessel repairs caused a delay in sampling causing the cruise to extend into a third week. In 2013, weather delays caused sampling to extend to a third week in June and September.

2.2.3.3 Biological Sampling

All blue crabs are counted and the sum weight of the catch is recorded. Carapace width, sex, maturity stage, and sponge color are recorded for all mature female blue crabs and from all subsampled blue crabs.

Beginning in September 2002, catches of blue crabs that were too large to process efficiently in the field were set aside for processing later. Subsamples were taken if the amount of crabs in the catch consisted of about ¼ of a 50-lb orange basket or more. The subsampling process involved dumping the basket on the culling table and immediately dividing the sample into quarters. The carapace width and sex were recorded and the sum of the crab weights in the subsample was taken. The remaining crabs (the other three quarters) were counted and mature females segregated. The sum weight of mature females was recorded and the carapace width of mature females was taken.

In 2005, the subsampling protocol was modified for situations where the number of blue crabs caught exceeds 100 individuals. In this situation, all mature females are separated, counted, weighed, and measured. The sum weight of all remaining crabs (males and immature females) is recorded before being subdivided into quarters. One quarter of the sample is then processed, recording the same data that are recorded for samples with fewer than 100 crabs. This process is repeated if necessary until a minimum of 100 crabs are measured.

2.2.3.4 Biases

One shortfall is that this survey, due to the vessel's size, cannot sample shallow water. The survey also cannot sample areas with complex benthic structure, like stumps or other submerged aquatic vegetation. These two limitations could omit important blue crab habitat.

Mature female blue crabs are present throughout the waterways of North Carolina. When it is time to spawn, mature females migrate to the oceanic inlets. Depending on the timing of sampling, the migration could artificially inflate the perceived abundance of mature females in Pamlico Sound by including transient, not resident, mature female crabs.

2.2.3.5 Development of Estimates

Effort is defined at the sample level with a sample consisting of double rigged trawls towed for 20 minutes. Precision of CPUE estimates was evaluated using the proportional standard error (PSE). Index values are design-based but data is available to develop model-based estimators (e.g. GLM). Indices represent the relative abundance of recruit, fully recruited, and mature female blue crabs in the survey.

A total of 3,153 samples captured 150,878 blue crabs from 1987 to 2016 (Table 2.4). The number of samples per year ranged from 90 to 108. The number of blue crabs caught annually ranged from 106 to 15,524. The modal peak for blue crabs captured in June was 50 mm CW, with approximately 50% of blue crabs occurring in the 40 mm to 70mm CW bins (Figure 2.15). In September there were modal peaks at both the 60 mm and 130 mm CW bins. The CW for blue crab ranged from 5 to 235 mm in June and from 14 to 200 mm in September (Figures 2.16). The mean CW in June appears to show a declining trend through the time series, averaging 83 mm from 1987-2003 and falling to an average of 71 mm from 2004 to 2016. The mean CW in September varied little throughout the time series, hovering around 100 mm.

Examination of the available data lead to the development of sex-specific indices of relative abundance for blue crab recruits (crabs less than 127 mm CW) and fully recruited blue crabs separately by month, and a September index of mature female blue crabs. To generate the sex-specific indices, when individual sex information was unavailable the overall male:female sex ratio by stage (recruit 49.3:50.7 and fully recruited 37.3:62.7) was applied to the unsexed portions of the catch. To account for the different sizes of the strata sampled, a weighted CPUE was used for the indices based on the number of grids in each stratum (Table 2.3).

The annual June weighted CPUE (wCPUE) for both male and female recruits shows inter-annual variability with an overall declining trend through the time series (Figure 2.17). Male recruit wCPUE ranged from a high of 55.3 in 1997 to a low of 3.9 in 2009. Female recruit wCPUE ranged from a high 62.6 in 1997 to a low of 4.7 in 2009. The annual September wCPUE for both male and female recruits was much higher in the earlier years of the time series and have been at stable low levels since 2000 (Figure 2.18). Male recruit wCPUE ranged from a high of 12.2 in 1996 to a low of 0.7 in 2011 and 2015. Female recruit wCPUE ranged from a high of 14.9 in 1996 to a low of 0.4 in 2008.

The annual June weighted CPUE (wCPUE) for both male and female fully recruited blue crabs shows inter-annual variability with an overall declining trend through the time series (Figure 2.18). Male fully recruited wCPUE ranged from a high of 10.0 in 1999 to a low of 0.1 in 2007 and 2009. Female fully recruited wCPUE ranged from a high 9.6 in 2004 to a low of 0.5 in 2007. The annual September wCPUE for both male and female fully recruited blue crabs were higher in the earlier years of the time series and have been at stable low levels since 2000. Male fully recruited wCPUE ranged from a high of 7.2 in 1996 to a low of <0.1 in 2006. Female recruit wCPUE ranged from a high of 26.6 in 1996 to a low of 0.3 in 2014.

The September mature female wCPUE has been variably but generally low since 2000 (Figure 2.19). Mature female wCPUE ranged from a high of 29.2 in 1996 to a low of 0.3 in 2014.

The abundance indices were standardized for assessment model input. See Section 2.2.1.5 for CPUE standardization procedure.

2.2.3.6 Estimates

The GLM model frequently selected strata, salinity, water temperature and water depth as significant covariates for male and female recruits and fully recruited crabs. All standardized indices showed an overall declining trend over years with a rebound since 2007 (Figures 2.20).

2.2.4 SEAMAP Trawl Survey

2.2.4.1 Survey Design and Methods

This program is a shallow water trawl survey to monitor the status and trends of coastal species in the South Atlantic Bight, including fish, shrimp, crabs, horseshoe crabs, sea turtles, mantis shrimp, and squid, to amass a long-term data base for research and fisheries management use. Samples are taken by trawl from the coastal zone of the South Atlantic Bight between Cape Hatteras, North Carolina, and Cape Canaveral, Florida (Figure 2.21).

Strata are delineated by the 4-m depth contour inshore and the 10-m depth contour offshore. Stations are randomly selected from a pool of stations within each stratum. The number of stations sampled in each stratum is determined by optimal allocation. A total of 102 stations are sampled each season within twenty-four shallow water strata.

The R/V Lady Lisa, a 75 ft. (23 m) wooden-hulled, double-rigged, St. Augustine shrimp trawler owned and operated by SCDNR, is used to tow paired 75 ft. (22.9 m) mongoose-type Falcon trawl nets without turtle excluder devices. The body of the trawl is constructed of #15 twine with 1.875 in (47.6 mm) stretch mesh. The cod end of the net is constructed of #30 twine with 1.625 in (41.3 mm) stretch mesh and is protected by chafing gear of #84 twine with 4 inch (10 cm) stretch "scallop" mesh. A 300 ft. (91.4-m) three-lead bridle is attached to each of a pair of wooden chain doors which measured 10 ft. x 40 in (3.0 m x 1.0 m), and to a tongue centered on the head-rope. The 86-ft (26.3 m) head-rope, excluding the tongue, had one large (60 cm) Norwegian "polyball" float attached top center of the net between the end of the tongue and the tongue bridle cable and two 9-in (22.3 cm) PVC foam floats located one-quarter of the distance from each end of the net webbing. A 1ft chain drop-back is used to attach the 89-ft. foot-rope to the trawl door. A 0.25-in (0.6 cm) tickler chain, which is 3.0 ft. (0.9 m) shorter than the combined length of the foot-rope and drop-back, is connected to the door alongside the foot-rope.

Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1 hour after sunrise to 1 hour before sunset). Contents of each net are sorted separately to species, and total biomass and number of individuals are recorded for all species of finfish, elasmobranchs, decapod and stomatopod, crustaceans, cephalopods, sea turtles, xiphosurans, and cannonball jellies. Only total biomass is recorded for all other miscellaneous invertebrates (excluding cannonball jellies) and algae, which are treated as two separate taxonomic groups.

Where large numbers of individuals of a species occur in a collection, the entire catch is sorted and all individuals of that species are weighed, but only a randomly selected subsample are processed and total number is calculated. For large trawl catches, the contents of each net are weighed prior to sorting and a randomly chosen subsample of the total catch is then sorted and processed. In every collection, each of the priority species is weighed collectively and individuals are measured. For large collections of the priority species, a random subsample consisting of thirty to fifty individuals is weighed and measured. Depending on the species, measurements of finfish are recorded as total length or fork length, measured to the nearest centimeter.

Additional data are collected on individual specimens of penaeid shrimp, blue crabs, sharks, horseshoe crabs, and sea turtles. Gonad and otolith specimens are also collected during seasonal cruises. A representative sample of specimens from each centimeter size range within each stratum are measured to the nearest mm (TL and SL), weighed to the nearest gram, and assigned a sex and maturity code. Sagittal otoliths and a representative series of gonadal tissue are removed, preserved, and transported to the laboratory at MRRI, where samples are processed. Hydrographic data collected with a Seabird SBE-19 CTD profiler at each station.

Fewer (78) stations were sampled in the same strata by the trawl survey in 1990-2000. In 1990-2000, stations were sampled in deeper strata with station depths ranging from 10 to 19 meters to gather data on the reproductive condition of commercial penaeid shrimp. Those strata were abandoned in 2001 to intensify sampling in the shallower depth-zone. From 2001 to 2008, a total of 102 stations were sampled each season (306 stations/year) within twenty-four shallow water strata, representing an increase from 78 stations previously sampled in those strata by the trawl survey (1990-2000). In 2009, the number of stations sampled each season increased to 112 (336 total). In the spring of 2013, the Raleigh Bay region of the North Carolina coast was not sampled due to weather and boat issues

2.2.4.2 Sampling Intensity

Multi-legged cruises are conducted in spring (early April - mid-May), summer (mid-July - early August), and fall (October - mid-November).

2.2.4.3 Biological Sampling

The contents of each net are sorted separately to species, and total biomass and number of individuals are recorded for all species of finfish, elasmobranchs, decapod and stomatopod crustaceans, and cephalopods. Only total biomass is recorded for all other miscellaneous invertebrates and algae, which are treated as two separate taxonomic groups. Marine turtles captured incidentally are measured, weighed, tagged, and released according to NMFS permitting guidelines. When large numbers of specimens of a species occur in a collection, the entire catch is sorted and all individuals of that species are weighed, but only a randomly selected subsample is processed and total number is calculated. For trawl catches where visual estimation of weight of total catch per trawl exceeds 500 kg, the contents of each net are weighed prior to sorting and a randomly chosen subsample of the total catch is then sorted and processed. In every collection, each of the twenty-seven target species is weighed collectively and individuals are measured to the nearest centimeter. For large collections of the target species, a random subsample consisting of thirty to fifty individuals is weighed and measured.

2.2.4.4 Biases

While sampling covers many different bottom types, tows cannot be conducted over hard bottom structures such as artificial reefs where blue crabs have been observed.

2.2.4.5 Development of Estimates

A total of 2,107 samples captured 4,086 blue crabs from 1989 to 2016 (Table 2.5). The number of samples per year ranged from 39 to 102. The number of blue crabs caught annually ranged from 22 to 715. Most blue crabs were captured in the summer portion of the survey (approximately 81%). The modal peak for blue crabs captured in the spring was 140 mm CW and 130 mm CW in both the summer and fall (Figure 2.22). The CW for blue crab ranged from 65 to 184 mm in the spring, 42 to 200 mm in the summer and from 36 to 175 mm in the fall (Figures 2.23). The mean CW in spring is difficult to interpret because in many years no blue crabs were caught or measured. The mean CW in the summer was variable but averaged approximate 130 mm through the time series. The mean CW in the fall was variable but is difficult to interpret due to low catch numbers.

Examination of the available data lead to the development of a summer index of relative abundance for mature female blue crabs. Most blue crabs captured in the summer are female (Figure 2.24) and although maturity stage is not recorded, immature females are rare in the survey (SCDNR personal communication). In developing the estimate all female blue crabs were assumed to be mature.

The September mature female wCPUE has been variably but generally low since 2007 (Figure 2.25). Mature female wCPUE ranged from a high of 22.8 in 1990 to a low of 0.3 in 2008.

The abundance indices were standardized for assessment model input. See Section 2.2.1.5 for CPUE standardization procedure.

2.2.4.6 Estimates

The GLM model selected salinity and water temperature as significant covariates for explaining annual variation in spawner abundance index from SEAMAP. The standardized spawner index declined to a low level since 2008 (Figures 2.26).

3 ASSESSMENT

3.1 Overview

3.1.1 Scope

In this assessment, the unit stock contains all blue crabs occurring within North Carolina coastal fishing waters, and the assessment is conducted for the time period of 1995-2016.

3.1.2 Previous Method

Establishing a comprehensive stock assessment (e.g., statistical catch-at-age or catch-at-length analysis; Quinn and Deriso 1999) for blue crab has been challenging. Determination of age for blue crabs is still an unresolved issue or is at best uncertain because they do not retain any hard parts throughout their life cycle, such as otoliths and scales. This difficulty in ageing has limited the application of age-based and length-based analysis for blue crabs (Hilborn and Walters 1992).

The surplus production model and the traffic light method have been used in the 2004 (Eggleston et al. 2004) and 2011 (NCDMF 2011) blue crab stock assessment in North Carolina, respectively. The surplus production model, as one of the age-aggregated methods, does not require any age-structure, but may fail to produce reliable estimates for management purposes when data lack contrast or when fluctuations in recruitment rather than harvest intensity drive population dynamics, and it cannot incorporate a recruitment or spawner abundance index even if available (Hilborn and Walters 1992). The traffic light method is a qualitative approach that heavily relies on abundance indices as indicators (e.g., Halliday et al. 2001; Ceriola et al. 2007). Selection of indicators and determination of thresholds are arbitrary and conclusions are limited to theoretical applications.

Catch-survey analysis (Collie and Sissenwine 1983) has been widely applied to crustaceans that are difficult to age (e.g., Zheng et al. 1997; Cadrin 2000), and has been adapted to blue crab stock assessments along the east coast of the USA with various modifications (e.g., Eggleston et al. 2004; Murphy et al. 2007; Wong 2010; Miller et al. 2011; VanderKooy 2013). For example, the 2011 Chesapeake Bay blue crab stock assessment used a sex-specific catch-survey analysis (Miller et al. 2011), and 2007 Florida blue crab stock assessment applied a catch-survey analysis with a 6-month time step (Murphy et al. 2007). Instead of requiring a full age structure, as in an age-based model, the catch-survey analysis splits the population into two stages in which the recruit stage can be easily distinguished from the fully recruited stage containing older animals. The animals in the recruit stage grow to the fully recruited stage at the next time step, which is the same assumption in age-based models if the time step is one year.

For North Carolina blue crabs, catch-survey analysis was attempted in the 2004 stock assessment but was not included in development of the management plan (Eggleston et al. 2004). Major reasons that catch-survey analysis was not adopted in recent stock assessments include: (1) lack of information to determine the partial fishing mortality on recruits and natural mortality, (2) environmental factors play an important role in population variability, (3) recruitment is very dynamic, and (4) abundance indices show spatial variation and the lack of a state-wide index.

3.1.3 Summary of Current Method

In this assessment, the working group developed a sex-specific two-stage model that is adapted from catch-survey analysis for assessing North Carolina blue crabs. In this model, a sex-specific recruits fishery selectivity and a sex- and stage-specific natural mortality are assumed free parameters to estimate based on data; standardized abundance indices were used to avoid influences of environmental factors on annual trend, including spatial locations and geographic features such as sediment size and bottom habitat structure; recruitment was modeled as free parameters to estimate instead of assuming any spawner-recruitment relationship; both process error and observation error were included to account for natural variation in population additional to the variation in response to harvesting; the Bayesian approach was applied to sufficiently incorporate data uncertainty and expert opinion in parameter estimation.

3.2 Two-Stage Model

3.2.1 Model Structure and Assumptions

In the two-stage model (also known as catch-survey analysis, Figure 3.1), the blue crab population consists of two stages, the recruit and the fully recruited crabs (Collie and Sissenwine 1983). The recruit stage contained crabs smaller than 127 mm CW, that is the legal harvestable size for male and immature female blue crabs in North Carolina, and the fully recruited stage included crabs larger than or equal to 127 mm CW. In the model, all fully recruited blue crabs were subject to fishing mortality, and the recruits were subject to a partial fishing mortality because mature females at this stage are harvestable, and those male and immature female blue crabs at this stage may also be retained if so long as they do not account for more than 10% of the catch. The population was modeled at annual time step. All recruits became fully recruited at the beginning of the next year. The population dynamics of blue crab in the sex-specific two-stage model was described in terms of the number of male and female crabs at each stage over time (Miller et al. 2011):

Population size of fully recruited animals

$$N_{y+1,\,s} = \left(N_{y,\,s}\exp\left(-M_{N,\,s} - F_{N,\,y,\,s}\right) + R_{y,\,s}\exp\left(-M_{R,\,s} - F_{R,\,y,\,s}\right)\right)\exp\left(\varepsilon_{N,\,y+1,\,s}\right),$$

Population size of recruits

$$R_y = \bar{R}\exp\left(\varepsilon_{R,\,y}\right),$$

$$R_{y,\,s} = R_y v_s,$$

Catch of fully recruited animals

$$C_{N,\,y,\,s} = \left(\frac{F_{N,\,y,\,s}}{F_{N,\,y,\,s} + M_{N,\,s}}\left(1 - \exp\left(-M_{N,\,s} - F_{N,\,y,\,s}\right)\right)N_{y,\,s}\right)\exp\left(\varepsilon_{CN,\,y,\,s}\right),$$

Catch of recruits

$$C_{R,\,y,\,s} = \left(\frac{F_{R,\,y,\,s}}{F_{R,\,y,\,s} + M_{R,\,s}}\left(1 - \exp\left(-M_{R,\,s} - F_{R,\,y,\,s}\right)\right)R_{y,\,s}\right)\exp\left(\varepsilon_{CR,\,y,\,s}\right),$$

Fishing mortality of fully recruited animals

$$F_{N,\,y,\,s} = F_y g_{N,\,s},$$

Fishing mortality of recruits

$$F_{R,\,y,\,s} = F_y g_{R,\,s},$$

Population size of spawners

$$N_{sp,\,y} = N_{y,\,s=female} w_N + R_{y,\,s=female} w_R,$$

Abundance indices of spawners

$$I_{sp,\,y,\,j} = \left(q_{sp,\,j} N_{sp,\,y}\right)\exp\left(\varepsilon_{sp,\,y,\,j}\right),$$

Abundance indices of fully recruited animals

$$I_{N,\,y,\,s,\,j} = \left(q_{N,\,s,\,j} N_{y,\,s}\right)\exp\left(\varepsilon_{IN,\,y,\,s,\,j}\right),$$

Abundance indices of recruits

$$I_{R,\,y,\,s,\,j} = \left(q_{R,\,s,\,j} R_{y,\,s}\right)\exp\left(\varepsilon_{IR,\,y,\,s,\,j}\right),$$

where R and N are the population size of recruits and fully recruited animals at the beginning of the year respectively, M and F are natural mortality and fishing mortality, v is the proportion of male or female in recruits, C is catch in number, g is selectivity, w is proportion of matured female in female recruits or female fully recruited animals, I is fishery-independent abundance index, q is the catchability; $\varepsilon_{N,\,y+1,\,s} \sim Normal\left(0,\,\sigma_N^2\right)$ and $\varepsilon_{R,\,y} \sim Normal\left(0,\,\sigma_R^2\right)$ are process errors, and $\varepsilon_{CN,\,y,\,s} \sim Normal\left(0,\,\sigma_{CN,\,s}^2\right)$, $\varepsilon_{CR,\,y,\,s} \sim Normal\left(0,\,\sigma_{CR,\,s}^2\right)$, $\varepsilon_{sp,\,y,\,j} \sim Normal\left(0,\,\sigma_{sp,\,j}^2\right)$, $\varepsilon_{IN,\,y,\,s,\,j} \sim Normal\left(0,\,\sigma_{IN,\,s,\,j}^2\right)$, and $\varepsilon_{IR,\,y,\,s,\,j} \sim Normal\left(0,\,\sigma_{IR,\,s,\,j}^2\right)$ are observation errors, which follow a normal distribution with a mean of zero and a standard deviation of σ; the subscript y indexes the yth year, s represents either male or female, j indexes the jth fishery-independent abundance index, R and N in subscripts denote the recruits and the fully recruited respectively, sp in subscripts denotes spawner.

In the model, a 1:1 sex ratio and sex-specific natural mortalities ($M_{N,\,s}$ and $M_{R,\,s}$) were assumed. The natural mortality was assumed constant over time. The mature female proportion for female recruits (w_R) and female fully recruited (w_N) was set to be 0.044 and 0.9 (Eggleston et al. 2004). The selectivity for fully recruited animals ($g_{N,\,s}$) was set to be one (Rudershausen and Hightower 2016), and selectivity for recruits ($g_{R,\,s}$) was assumed sex-specific and free parameters to estimate in the model. The annual recruitment $R_{y,s}$ was directly estimated to avoid assuming a fixed spawner-recruitment relationship because the spawner size can often only explain a small amount of the high variation in recruitment (Jiao et al. 2012). The annual recruitment $R_{y,s}$ was assumed to follow a lognormal distribution that centers around an average of $\bar{R}$. In North Carolina, fall is the primary spawning season for blue crab, and most harvest occurs during May-October. Thus, in the model, indices sampled since September in the current year (i.e., the P100 fall and P195 September indices) were related to the abundance in the following year, except for the spawner indices (i.e., P195 spawner and SEAMAP spawner indices).

3.2.2 Model Calibration

In this assessment, the Bayesian approach was applied to estimate parameters. The posterior distribution was obtained through the Metropolis-Hasting algorithm using Markov Chain Monte Carlo (MCMC) simulation (Hilborn et al. 1994; Hoff 2009). Three concurrent chains were run with a total of 500,000 iterations for each chain. The first 470,000 iterations were discarded as burn-in and every 10th iteration from the remaining sample from each chain was used for analysis. The working group used JAGS (Version 4.0.1) to run the Bayesian analysis.

Noninformative priors were used, i.e., uniform priors, for initial population size ($N_{y=1997,\,s}$), averange annual recruitment ($\bar{R}$), fishing mortaltiy (F_y), recruts selectivity ($g_{R,\,s}$), catchability ($q_{sp,\,j}$, $q_{N,\,s,\,j}$ and $q_{R,\,s,\,j}$), and standard deviation (σ_N, σ_R, σ_{CN}, σ_{CR}, $\sigma_{sp,\,j}$, $\sigma_{IN,\,s,\,j}$ and $\sigma_{IR,\,s,\,j}$) of process and obseration errors. The working group constructed a hierarchical prior for natrual mortality parameters where $M_{N,\,s}$ and $M_{R,\,s}$ follow an unknown lognormal distribution centering around $\bar{M}$ that is further governed by a uniform distribution bounded by m_1 and m_2:

$$M_{N,\,s} \;\; or \;\; M_{R,\,s} = \bar{M}\exp\left(\varepsilon_M\right),$$

$$\bar{M} \sim Uniform\left(m_1,\,m_2\right),$$

where $\varepsilon_M \sim Normal\left(0,\,\sigma_M\right)$ is a random error. Priors and parameters are listed in Tables 3.1 and 3.2.

3.2.3 Sensitivity Analysis

In addition to the baseline model above (Model 1), the working group considered three more candidate models (Models 2-4, Table 3.3). These candidate models were similar to Model 1 except that the Model 2 assumed a constant unknown natural mortality over sex and stage; Model 3 used a constant known natural mortality (M = 0.55; Eggleston et al. 2004) for both sexes and stages; Model 4 assumed a Ricker stock-recruitment model for recruits (Ricker 1954):

$$R_{y+1} = \left(\alpha N_{sp,\,y} \exp\left(-\beta N_{sp,\,y}\right)\right) \exp\left(\varepsilon_{R,\,y+1}\right),$$

$$\varepsilon_{R,\,y} \sim N\left(0,\, \sigma_R^2\right),$$

where α is the productivity parameter that represents the number of recuits per spawner at low density of spawners and is proportional to fecundity, β ($\beta > 0$) is the density-dependent parameter that controls the level of density dependence. Other major sensitivity runs that the working group have tested but are not presented here include time-block catchability, random-walk catchability, recruits June index only, recruits September index only, initial year of 1997 (when abundance indices start), sex-constant recruits selectivity to estimate, sex-constant recruits selectivity to input (0.03; Rudershausen and Hightower 2016), sex-constant recruits natural mortality, wider natural mortality constraint, and fixed catch and index standard deviation input.

The working group also conducted a retrospective analysis on spawner abundance and F for the baseline model (Model 1), which estimates the systematic changes in these two parameters as additional years of data were added (Mohn 1999). The working group started with the data from 1995 to 2011, and added one additional year of data at a time up to 2016. The retrospective error is calculated as follows (Mohn 1999; Hurtado-Ferro et al. 2015):

$$\frac{1}{n_{peel}} \sum_{t=2016-n_{peel}}^{2016} \frac{X_t \middle| data\ to\ year\ t - X_t \middle| data\ to\ year\ 2016}{X_t \middle| data\ to\ year\ 2016},$$

where X = spawner abundance or F, and n_{peel} = 5 is the total number of years that are “peeled off”. Hurtado-Ferro et al. (2015) suggested a range between -0.22 and 0.3 for short-lived species that any values falling outside this range should indicate a problem of retrospective error and should be cause for concern. Retrospective error may either result from inconsistent or insufficient data, or result from natural variation in population dynamics.

3.2.4 Results

In the baseline model, catch data were fitted well but the fits of abundance index data were not as well as the catch data (Figures 3.2-3.3). Estimated catch for both sexes and both stages declined overall from 1995 to 2016 with a rebound occurring near 2007, especially for fully recruited crabs, but the estimated catch remained low since then (Figure 3.2). The models yielded a declining trend in all abundance indices before 2007 and a rebound afterwards (Figure 3.3). High uncertainty was associated with early years’ index estimates either due to lack of data (e.g., 1995 and 1996 in some indices) or due to large across-year variation in index data (e.g., 2007-2014 of P100 indices).

Estimated population size of male recruits, female recruits and overall recruitment showed an overall declining trend with some intermittent periods of population increase, especially the period of 2007-2013 (Figure 3.4). Estimated population size of fully recruited male, female and spawners remained high until a sharp decrease starting in 1998, then followed by a rebound starting in 2007. This rebound sustained the population size of fully recruited females and spawners approximately 50%-75% of those in mid 1990s, and sustained the population size of fully recruited males almost equivalent to the level in mid 1990s. Females had higher natural mortality estimates than males (Figure 3.5). Natural mortality estimates for fully recruited females were associated with higher uncertainty than other stages.

The estimated fishing mortality was high from 1995 to 2006, with a mean ranging from 1.78 to 2.64 (Fig. 3.6). Starting in 2007, fishing mortality estimates decreased to at least 50% of those before 2007, with a mean ranging from 0.72 to 1.49 and the lowest value of 0.72 occurring in 2013. Estimates of fishing mortality in the early years before 2007 were associated with large uncertainty.

Retrospective analysis showed consistent estimates of spawner abundance and F with additional years of data added (Figure 3.7). The retrospective errors for spawner abundance and F were 0.012 and 0.018, respectively, which fell within the recommended range of -0.22–0.3 and suggested that the retrospective error is less of a concern in this analysis.

The four candidate models produced consistent outcomes (Figures 3.8-3.12). In the two candidate models with sex- and stage-constant natural mortality, the estimated natural mortality from Model 2 (mean = 0.48 and 95% credible interval, 95%CI = 0.4-0.68) was close to the one input in Model 3 (0.55; Figure 3.11). Recruitment estimates from Models 1-3 showed density-dependence (Figure 3.13). At low spawner population size, estimated recruitment tended to be high with more spawners, but tended to decline with more spawners at high spawner population size.

3.2.5 Discussion

The previously established minimum size limit of five inches (127 mm) for North Carolina blue crabs was maintained in the 1998 Fishery Management Plan (FMP), with mature females, soft, and peeler crabs exempted from this size limit. The Blue Crab FMP was amended in 2004 by adopting a spawning stock trigger meant to protect the spawning stock. The 2004 Amendment implemented a seasonal maximum size limit for mature females (6.75 inch for hard crabs and 5.25 inch for peeler crabs) from September 1 through April 30 when the spawning trigger was met. The seasonal maximum size limit was enacted in 2006 and remained in effect through April 2014. This may have contributed to the large reduction in fishing mortality estimates and the rebound in population size estimates, especially for fully recruited female crabs and the boost in SPR estimates since 2007, although industry compliance with this measure is uncertain.

Blue crab is sensitive to flow and salinity, larval and juvenile crabs depends on flow to distribute spatially before settling down (Etherington and Eggleston 2000). North Carolina experienced three sequential destructive hurricanes in 1999, namely Dennis (end of August), Floyd (mid-September) and Irene (mid-October). Heavy rainfall during the first two hurricanes caused massive flooding, reduced salinity, and anoxic conditions in the Pamlico and Neuse River systems, which forced blue crabs out of the rivers and aggregate in Pamlico Sound where the harvest of crabs was high in 1999 (Paerl et al. 2001; Burgess et al. 2007). Statewide catch of fully recruited crabs and female recruits in 1999 was among the highest of the study time period. Low recruitment estimates during 2000-2001 in this assessment may represent a recruitment failure due to the low spawning stock size caused by intense harvest of spawners after the 1999 hurricane season and the potential disruption in larval dispersal and initial settlement caused by the hurricanes (Etherington and Eggleston 2000; Eggleston et al. 2004).

The models fit to index data not as well as to catch data, which reflects the quality of these different types of index datasets. For example, in the SEAMAP spawner data, all samples in certain years (e.g., 1992, 2015) were collected in July, samples in certain years (e.g., 2014, 2016) were collected in both July and August, and samples in certain years such as 2014 were not well balanced among month or location, e.g., in 2014, 27 samples were collected in July versus only four samples were collected in August; all these July samples were from Raleigh Bay and Onslow Bay, and these August samples were from Long Bay. Thus, a sampling scheme that is consistent and well-balanced across year and region would provide better-quality data to improve the model fit to index data.

This assessment did not include discards due to a lack of data. However, discards of blue crabs in North Carolina waters could be a significant source of mortality, especially in the commercial gill net fishery. This assessment, without discards considered, could be overestimating population size. Thus, it is important to establish data collection programs for fishery discards to help improve future stock assessments.

4 STATUS DETERMINATION

The General Statutes of North Carolina define overfished as "the condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate for the recruitment class of a fishery to replace the spawning class of the fishery" (NCGS § 113-129). The General Statutes define overfishing as "fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest."

The 2004 FMP for blue crab defined the overfished condition for the blue crab stock based on commercial landings trends (NCDMF 2004). The blue crab resource was considered overfished when annual commercial landings declined for five consecutive years. No overfishing definition was developed.

The 2011 FMP for blue crab defined the overfished condition based on the blue crab production characteristic of the Traffic Light such that when the proportion of red for the production characteristic is greater than or equal to the third quartile (>=0.75) for three consecutive years, the blue crab stock is considered overfished. No overfishing definition was developed.

In this assessment, the working group evaluated blue crab stock status based on maximum sustainable yield (MSY). The MSY-based biological reference points (BRPs) have been widely used in fishery stock assessments including blue crabs, e.g., Chesapeake Bay 2001 (Miller et al. 2011), Florida 2007 (Murphy et al. 2007) and Gulf of Mexico 2013 assessments (VanderKooy 2013). In this assessment, the MSY-based BRPs were developed by estimating a Ricker spawner-recruit relationship outside the two-stage model (Shepherd 1982). Specifically,

Spawner-per-recruit (SPR) (Quinn and Deriso 1999)

$$SPR = v_{s=female}\left(w_R + w_N \frac{\exp\left(-Fg_{R,\, s=female} - M_{R,\, s=female}\right)}{1-\exp\left(-Fg_{N,\, s=female} - M_{N,\, s=female}\right)} \right),$$

Yield-per-recruit (YPR)

$$YPR = \sum_s \left(\frac{v_s Fg_{R,s}}{Fg_{R,s} + M_{R,s}} \left(1 - \exp\left(-Fg_{R,s} - M_{R,s}\right)\right)\right) + \sum_s \left(\frac{v_s Fg_{N,s}}{Fg_{N,s} + M_{N,s}} \exp\left(-Fg_{R,s} - M_{R,s}\right)\right),$$

Equilibrium spawner abundance

$$N_{sp}^{*} = \frac{\ln(\alpha) + \ln(SPR)}{\beta},$$

Equilibrium recruitment

$$R^{*} = \frac{N_{sp}^{*}}{SPR},$$

Total yield

$$Total\ \ yield = R^{*} \times YPR .$$

The fishing mortality that maximizes the total yield (F_{MSY}) was set to be the threshold for overfishing, and $0.75F_{MSY}$ was set to be the target fishing mortality. The spawner abundance at F_{MSY} (SP_{MSY}) and 0.75 F_{MSY} was set to be the threshold and target for overfished population, respectively. In the current stock assessment, the populaion is determined being overfished if the average spawner abundance in 2016 falls below SP_{MSY}, and is determined to be undergoing overfishing if the average F in 2016 remains above F_{MSY}.

For the current assessment (2016), determination of the current population status is based on the baseline model (Figure 3.6). In the baseline model, the threshold SP_{MSY} was estimated to be 64 million on average, and the target spawner abundance was estimated to be 73 million on average. The average spawner abundance of the year 2016 was estimated to be 50 million (< the threshold) with a 95%CI of 37-68 million, which determines the population in 2016 is overfished with a probability of 0.98. In the baseline model, the F threshold F_{MSY} and F target $0.75F_{MSY}$ was estimated to be 1.46 and 1.22 on average respectively, and the fishing mortality of 2016 was averaged 1.48 (> F threshold) with a 95%CI of 0.86-2.42, which determines overfishing is occurring in 2016 with a probability of 0.52.

In this assessment, the working group did not use spawning potential ratio (SPR/SPR at virgin level) based BRPs that compare with the virgin level, e.g., North Carolina 2004 assessment (Eggleston et al. 2004) and Louisiana 2016 assessment (West et al. 2016). This assessment spans from 1995 to 2016 due to data limitation, and the fishery began in the 1950s. The model may not sufficiently capture the population dynamics back to the virgin level due to such a short time series of data relative to history of the fishery, which makes it difficult to obtain reliable BRP estimates that compare with the virgin level.

5 SUITABILITY FOR MANAGEMENT

Stocks assessments performed by the NCDMF in support of fishery management plans are subject to an extensive review process. Internal reviews are conducted by various groups within the NCDMF including the species plan development team and the Management Review Team. External reviews are designed to provide an independent peer review and are conducted by experts in stock assessment science and experts in the biology and ecology of the species. The goal of the external review is to ensure the results are based on sound science and provide a valid basis for management. The external peer reviewer panel accepted the baseline two-stage model as appropriate for management use for the next five years, and agree the determination of North Carolina blue crab stock status concurs with professional opinion and observations. The reviewers also agree that: (1) the justification of inclusion and exclusion of data sources are appropriate; (2) the data sources used in this assessment are appropriate; (3) the baseline two-stage model is a significant improvement over the traffic light approach used previously, and is robust to assumptions that have been explored in sensitivity analysis, such as assumptions regarding natural mortality and growth; (4) determination of stock status is robust to model assumptions; (5) although reviewers expressed concerns regarding spatial coverage of abundance indices and model complexity, sensitivity analysis indicates model results and stock status determination are robust to the reviewers' primary areas of concerns. Detailed comments from the external peer reviewers are provided in Appendix B, and results of additional sensitivity analyses requested by the reviewers are provided in Appendix C.

6 RESEARCH RECOMMENDATIONS

This assessment successfully applied a comprehensive stock assessment method, however, the performance of the assessment model could be improved with additional data. To address this, the following research recommendations are offered. Those research recommendations denoted with an asterisk (*) were suggested (and ranked) by the external peer reviewers.

<u>High</u>

- Develop statewide fishery-independent survey(s) to monitor the abundance of all blue crab life stages
- Expand time and area coverage of existing fishery-independent surveys
- Better characterize the magnitude of recreational harvest *
- Develop better estimates of life-history parameters, especially growth and natural mortality *
- Explore alternative biological reference points *

<u>Medium</u>

- Identify key environmental factors that significantly impact North Carolina's blue crab stock and investigate assessment methods that can account for these environmental factors
- Implement monitoring of hazardous events (e.g., hurricane, extreme heat or cold weather) affecting blue crab population dynamics and harvest
- Explore alternative model types *

<u>Low</u>

- Investigate and support research on promising methods to age blue crabs
- Evaluate the genetic stock structure of blue crabs within North Carolina and the magnitude of mixing between populations
- Identify programs outside the NCDMF that collect data of potential use to the stock assessment of North Carolina's blue crabs

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8 TABLES

Table 1.1. Water quality parameters required by and habitats associated with different life stages of blue crab. No documented data where blank (Funderburk et al.1991; Pattilo et al. 1997; Wannamaker and Rice (2000); NOAA 2001).

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

Table 1.2. Number of fishermen (excluding crew) that reported landings of blue crabs in North Carolina, associated number of trips, average crew size, and estimated total number of participants (fishermen + crew), 1994–2016.

Year	Number of Fishermen	Number of Trips	Average Crew Size	Total Participants
1994	2,059	121,833		
1995	2,211	125,974		
1996	2,287	123,900		
1997	2,284	132,493		
1998	2,004	143,055		
1999	1,916	124,378	1.40	2,690
2000	1,756	111,213	1.39	2,442
2001	1,787	113,571	1.41	2,526
2002	1,681	93,620	1.47	2,473
2003	1,578	91,730	1.45	2,292
2004	1,489	80,828	1.46	2,169
2005	1,216	64,029	1.43	1,735
2006	1,010	52,886	1.42	1,437
2007	952	53,833	1.46	1,387
2008	914	52,654	1.54	1,409
2009	990	59,313	1.60	1,587
2010	984	54,977	1.52	1,498
2011	925	52,406	1.59	1,472
2012	895	52,696	1.57	1,403
2013	863	52,630	1.55	1,340
2014	923	56,217	1.54	1,425
2015	923	57,603	1.58	1,454
2016	884	51,707	1.61	1,424

Table 1.3. Estimated number of blue crab directed recreational fishing trips compared to estimated total number of recreational fishing trips, and estimated number of blue crabs harvested and discarded by RCGL license holders in North Carolina, 2002–2008.

	Number of Trips		Percent of total trips	Harvest	Discards
Year	Total	Directed			
2002	80,159	28,324	35%	346,550	185,939
2003	55,787	27,907	50%	354,425	124,196
2004	53,488	28,021	52%	329,478	138,316
2005	47,120	26,278	56%	323,531	152,905
2006	43,384	24,401	56%	297,875	123,787
2007	41,617	25,153	60%	286,856	102,695
2008	40,556	24,732	61%	311,690	132,519

Table 1.4. Total effort and catch (in numbers of crabs) estimates based on CAP shellfish mail survey, 2011-2016.

Year	Wave	Total Effort	Total Harvest	Total Release	Total Catch
2011	Jan/Feb	658	2,253	1,287	3,540
	Mar/Apr	1,570	5,472	4,725	10,197
	May/Jun	8,253	36,477	19,310	55,786
	Jul/Aug	7,416	33,159	32,266	65,426
	Sep/Oct	5,333	29,034	20,718	49,752
	Nov/Dec	1,588	8,031	3,457	11,488
	Total	24,818	114,426	81,763	196,189
2012	Jan/Feb	781	1,215	330	1,545
	Mar/Apr	2,196	8,230	5,504	13,734
	May/Jun	7,311	23,564	14,762	38,326
	Jul/Aug	11,262	61,648	40,210	101,858
	Sep/Oct	3,625	19,563	13,405	32,968
	Nov/Dec	1,688	6,759	4,861	11,620
	Total	26,863	120,979	79,072	200,051
2013	Jan/Feb	161	0	0	0
	Mar/Apr	1,784	1,528	1,162	2,690
	May/Jun	6,225	23,150	11,528	34,678
	Jul/Aug	9,555	40,004	20,143	60,147
	Sep/Oct	10,599	25,976	25,872	51,848
	Nov/Dec	2,408	3,516	2,747	6,263
	Total	30,732	94,174	61,452	155,626
2014	Jan/Feb	335	0	0	0
	Mar/Apr	1,222	2,872	2,322	5,195
	May/Jun	8,477	25,749	18,019	43,768
	Jul/Aug	5,584	35,911	23,067	58,978
	Sep/Oct	7,282	35,882	23,975	59,856
	Nov/Dec	481	183	30	213
	Total	23,381	100,597	67,413	168,010
2015	Jan/Feb	760	0	0	0
	Mar/Apr	2,993	4,648	5,897	10,546
	May/Jun	5,182	22,461	14,429	36,890
	Jul/Aug	10,880	31,483	28,123	59,605
	Sep/Oct	5,743	12,309	8,925	21,234
	Nov/Dec	2,405	686	2,761	3,415
	Total	27,963	71,587	60,135	131,690
2016	Jan/Feb	1,218	0	0	0
	Mar/Apr	1,111	4,696	3,351	8,047
	May/Jun	5,192	16,720	18,446	35,166
	Jul/Aug	7,435	21,722	41,521	63,243
	Sep/Oct	7,537	40,047	19,157	59,204
	Nov/Dec	832	1,694	305	1,999
	Total	23,325	84,879	82,780	167,659

Table 1.5. Management measures in N.C. Blue Crab Fishery Management Plan Amendment 2 that may be implemented by proclamation as described in the blue crab adaptive management framework when a stock characteristic exceeds a designated management threshold.

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

Table 2.1. Frequency of occurrence, number of samples, CPUE, standard error, minimum number caught in a sample, maximum number caught in a sample, and total number caught by year for all blue crab from Program 120 core stations, 1971-2016.

Year	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crab
1971	100	3	6.00	1.53	3	8	18
1972*	.	.	.	.	.	.	.
1973	61.5	26	2.46	0.92	0	23	64
1974	79.2	24	20.42	6.55	0	120	490
1975	64.1	39	4.69	1.31	0	30	183
1976	66.7	14	15.21	5.37	0	52	213
1977	76.9	13	14.54	8.52	0	113	189
1978	64.4	87	3.09	0.60	0	39	269
1979	71.3	136	3.79	0.41	0	29	516
1980	77.2	145	4.42	0.49	0	34	641
1981	87.0	146	8.92	1.15	0	106	1,302
1982	85.7	154	8.44	1.03	0	102	1,299
1983	83.6	183	7.33	0.91	0	83	1,342
1984	86.6	186	8.64	0.92	0	114	1,607
1985	87.7	195	8.97	0.73	0	70	1,750
1986	74.5	204	5.33	0.67	0	92	1,087
1987	83.0	206	9.38	2.03	0	396	1,933
1988	80.4	209	10.23	1.30	0	124	2,139
1989	70.0	207	4.49	0.64	0	73	930
1990	78.2	206	7.57	0.80	0	64	1,559
1991	70.5	207	5.25	0.56	0	53	1,086
1992	66.3	208	4.36	0.53	0	71	907
1993	71.7	204	7.70	1.25	0	163	1,570
1994	77.6	205	8.12	1.39	0	237	1,665
1995	75.5	208	8.05	0.89	0	92	1,674
1996	83.6	207	13.50	1.37	0	107	2,794
1997	74.9	207	9.29	0.97	0	66	1,922
1998	69.2	208	6.51	0.86	0	115	1,354
1999	79.1	206	10.68	1.16	0	120	2,200
2000	77.9	208	4.40	0.45	0	47	915

Year	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crab
2001	67.3	208	7.55	1.54	0	285	1,571
2002	80.8	208	9.44	1.05	0	107	1,963
2003	70.2	208	5.75	0.74	0	90	1,197
2004	83.7	208	9.98	1.09	0	105	2,076
2005	75.0	208	6.49	0.84	0	122	1,350
2006	69.2	208	6.30	0.80	0	61	1,310
2007	68.8	208	5.52	0.75	0	95	1,149
2008	76.0	208	8.12	0.84	0	79	1,688
2009	65.9	208	7.80	1.52	0	202	1,622
2010	74.0	208	7.80	0.88	0	124	1,622
2011	74.0	208	7.43	0.76	0	78	1,546
2012	73.6	208	8.81	0.97	0	106	1,832
2013	65.4	208	3.58	0.46	0	51	744
2014	59.1	208	3.64	0.61	0	89	758
2015	69.7	208	5.85	0.83	0	126	1,216
2016	61.5	208	3.04	0.37	0	49	632

* No samples from core stations in 1972

Table 2.2. Frequency of occurrence, number of samples, CPUE, standard error, minimum number caught in a sample, maximum number caught in a sample, and total number caught by year for all blue crab from Program 100 core stations, 1972-2016.

Year	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crabs
1972	25.0	12	0.67	0.40	0	4	8
1973	25.0	28	0.39	0.15	0	3	11
1974	46.9	49	4.49	1.92	0	86	220
1975	62.5	24	2.67	0.90	0	16	64
1976	60.0	20	2.05	0.63	0	9	41
1977	66.7	18	1.72	0.46	0	7	31
1978	15.0	60	0.23	0.09	0	4	14
1979	10.8	37	0.16	0.09	0	3	6
1980	2.7	37	0.08	0.08	0	3	3
1981	34.2	38	0.74	0.22	0	6	28
1982	6.9	101	0.07	0.03	0	1	7
1983	11.7	137	0.15	0.04	0	3	21
1984	7.1	126	0.08	0.03	0	2	10
1985	47.6	147	1.04	0.13	0	7	153
1986	70.6	119	6.43	0.99	0	61	765
1987	48.8	162	1.57	0.27	0	22	254
1988	59.3	140	4.44	0.59	0	34	621
1989	43.6	140	2.90	0.70	0	49	406
1990	24.3	140	0.53	0.13	0	13	74
1991	36.4	140	0.73	0.13	0	12	102
1992	47.9	140	1.57	0.28	0	22	220
1993	32.9	140	0.63	0.10	0	6	88
1994	60.7	140	3.37	0.52	0	46	472
1995	81.4	140	5.78	0.79	0	62	809
1996	45.0	140	1.24	0.28	0	34	174
1997	7.9	140	0.11	0.04	0	4	15
1998	40.0	140	3.46	2.19	0	305	484
1999	58.6	140	4.89	1.37	0	180	684
2000	40.7	140	1.71	0.30	0	21	240
2001	25.0	140	0.46	0.09	0	9	65
2002	72.9	140	4.47	0.74	0	85	626
2003	68.6	140	6.71	0.89	0	51	940
2004	31.4	140	0.76	0.15	0	13	107
2005	62.5	128	2.23	0.32	0	25	286
2006	77.1	140	4.76	0.57	0	45	667
2007	74.3	140	4.34	0.59	0	51	607
2008	92.9	140	25.66	3.75	0	346	3593

Year	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crabs
2009	96.4	140	20.04	1.99	0	173	2806
2010	97.1	140	24.29	2.35	0	157	3401
2011	79.3	140	10.09	1.23	0	64	1413
2012	84.3	140	10.56	2.64	0	352	1479
2013	76.4	140	4.21	0.70	0	65	589
2014	55.0	140	3.67	0.64	0	40	514
2015	93.6	140	19.29	3.10	0	294	2700
2016	85.7	140	11.68	1.27	0	96	1635

Table 2.3. Number of sample grids per strata used as weighting factors for catch-per-unit-effort calculations for Program 195.

Strata	Strata Abbreviation	Number of Grids
Neuse River	NR	93
Pamlico River	PR	64
Pungo River	PUR	18
Pamlico Sound Deep East	PDE	554
Pamlico Sound Shallow East	PSE	206
Pamlico Sound Deep West	PDW	312
Pamlico Sound Shallow West	PSW	135

Table 2.4. Frequency of occurrence, number of samples, weighted CPUE, standard error, minimum number caught in a sample, maximum number caught in a sample, and total number caught by year for all blue crabs from Program 195, 1987 – 2016.

Year	Percent Frequency of Occurrence	Total Number of Samples	Weighted CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crabs
1987	92.7	96	68.83	12.33	0	769	6,806
1988	92.6	95	33.42	5.39	0	323	3,316
1989	90.0	90	45.13	8.52	0	551	3,890
1990	100	105	155.64	26.86	1	1,706	15,475
1991	86.8	106	138.04	21.07	0	1,521	14,967
1992	94.3	105	63.39	9.79	0	557	6,448
1993	97.2	107	62.27	9.72	0	508	6,416
1994	93.1	102	53.54	6.34	0	394	5,359
1995	100	105	31.70	4.16	1	193	3,607
1996	97.1	105	63.41	8.58	0	401	6,589
1997	96.2	106	71.39	10.21	0	430	7,467
1998	93.4	106	55.82	11.96	0	1,052	6,027
1999	93.4	106	76.24	8.28	0	374	8,207
2000	93.4	106	28.93	3.69	0	451	3,598
2001	69.8	106	31.25	5.95	0	277	3,111
2002	81.0	105	49.73	8.08	0	387	5,528
2003	85.8	106	56.51	12.25	0	800	5,817
2004	84.1	107	52.22	10.62	0	682	7,208
2005	88.5	104	27.05	3.78	0	217	3,213
2006	73.1	108	18.03	3.14	0	575	3,007
2007	77.1	105	12.54	2.73	0	156	1,590
2008	72.2	108	20.13	4.12	0	229	2,508
2009	66.7	108	6.53	1.45	0	152	952
2010	82.4	108	58.69	11.62	0	732	6,831
2011	76.9	108	15.72	4.15	0	337	2,557
2012	73.1	108	17.09	3.02	0	269	2,128
2013	72.2	108	25.04	5.17	0	334	2,578
2014	68.5	108	11.09	1.82	0	106	1,215
2015	66.7	108	9.16	2.64	0	515	1,656
2016	82.4	108	17.19	2.75	0	526	2,807

Table 2.5. Frequency of occurrence, number of samples, CPUE, standard error, minimum number caught in a sample, maximum number caught in a sample, and total number caught by year for all blue crabs from the SEAMAP Coastal Survey by season, 1989 – 2016.

	Spring							Summer							Fall						
Year	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crab	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crab	Percent Frequency of Occurrence	Total Number of Samples	CPUE	Standard Error	Minimum Number per Sample	Maximum Number per Sample	Total Number of Blue Crab
1989	0.0	13	0	.	.	.	0	46.2	13	2.38	0.78	0	7	31	61.5	13	2.23	0.66	0	7	29
1990	11.1	18	0.11	0.07	0	1	2	94.4	18	22.78	7.11	0	99	410	82.4	17	6.00	3.90	0	70	102
1991	22.2	18	0.22	0.10	0	1	4	61.1	18	4.00	2.45	0	46	72	29.4	17	0.82	0.57	0	10	14
1992	5.6	18	0.44	0.43	0	8	8	50.0	18	3.06	1.38	0	22	55	44.4	18	1.17	0.43	0	7	21
1993	11.1	18	0.17	0.12	0	2	3	61.1	18	16.72	6.14	0	83	301	33.3	18	1.89	1.02	0	18	34
1994	11.1	18	0.28	0.22	0	4	5	66.7	18	5.17	2.23	0	39	93	38.9	18	1.06	0.43	0	7	19
1995	0.0	18	0	.	.	.	0	50.0	18	4.50	1.87	0	32	81	11.1	18	0.11	0.07	0	1	2
1996	5.6	18	0.11	0.11	0	2	2	77.8	18	17.94	6.76	0	118	323	33.3	18	0.50	0.23	0	4	9
1997	22.2	18	0.33	0.16	0	2	6	50.0	18	2.06	0.71	0	10	37	5.6	18	0.22	0.22	0	4	4
1998	11.1	18	0.11	0.07	0	1	2	66.7	18	7.83	2.92	0	46	141	16.7	18	0.67	0.54	0	10	12
1999	5.6	18	0.06	0.05	0	1	1	38.9	18	1.00	0.36	0	5	18	38.9	18	2.39	1.27	0	23	43
2000	0.0	18	0	.	.	.	0	66.7	18	2.83	0.95	0	17	51	5.6	18	0.06	0.05	0	1	1
2001	6.5	31	0.10	0.07	0	2	3	54.8	31	8.52	4.73	0	145	264	29.0	31	0.58	0.24	0	6	18
2002	6.7	30	0.20	0.14	0	3	6	56.7	30	1.73	0.59	0	17	52	13.3	30	0.23	0.12	0	3	7
2003	6.7	30	0.23	0.20	0	6	7	43.3	30	1.97	0.57	0	11	59	46.7	30	0.77	0.19	0	4	23
2004	6.1	33	0.67	0.47	0	14	22	66.7	33	18.45	6.42	0	197	609	24.2	33	2.55	1.25	0	38	84
2005	12.1	33	0.21	0.13	0	4	7	39.4	33	3.97	1.28	0	31	131	9.1	33	0.12	0.07	0	2	4
2006	0.0	30	0	.	.	.	0	48.3	29	4.66	1.20	0	21	135	20.0	30	1.67	0.77	0	16	50
2007	0.0	28	0	.	.	.	0	25.0	28	1.54	0.87	0	21	43	0.0	28	0	.	.	.	0
2008	0.0	27	0	.	.	.	0	14.8	27	0.26	0.15	0	4	7	11.1	27	0.56	0.31	0	6	15
2009	0.0	30	0	.	.	.	0	36.7	30	2.23	1.36	0	41	67	3.3	30	0.03	0.03	0	1	1
2010	9.7	31	0.13	0.08	0	2	4	32.3	31	0.97	0.36	0	10	30	9.7	31	0.10	0.05	0	1	3
2011	36.4	33	1.06	0.57	0	19	35	30.3	33	1.82	0.66	0	17	60	33.3	33	0.76	0.24	0	5	25
2012	45.5	33	1.76	0.68	0	21	58	36.4	33	1.00	0.34	0	9	33	12.1	33	0.15	0.08	0	2	5
2013	21.1	19	0.21	0.09	0	1	4	40.0	30	1.13	0.34	0	7	34	23.3	30	0.50	0.20	0	4	15
2014	12.9	31	0.13	0.06	0	1	4	29.0	31	2.23	0.79	0	20	69	12.9	31	0.13	0.06	0	1	4
2015	3.2	31	0.03	0.03	0	1	1	23.5	34	1.74	0.74	0	16	59	9.7	31	0.52	0.34	0	9	16
2016	5.9	34	0.06	0.04	0	1	2	29.4	34	1.06	0.39	0	9	36	17.6	34	1.15	0.51	0	13	39

Table 3.1. Parameters and priors. U denotes uniform distribution.

Parameters	Values	Reference
Input parameters		
Sex ratio	1:1	
Selectivity for fully recruited	$g_{N,\,s}=1$	Rudershausen and Hightower 2016
Proportion of mature females	$w_N=0.9$; $w_R=0.044$	Eggleston et al. 2004
Natural mortality (Model 3)	M=0.55	Eggleston et al. 2004
Priors		
Initial population size (10^6)	$N_{y=1997,\,s=male} \sim$ U(58, 5800) $N_{y=1997,\,s=female} \sim$ U(58, 5800)	Derived from catch data in initial year (1995)[a]
Average recruitment (10^6)	$\bar{R} \sim$ U(10, 1000)	Derived from catch data[b]
Initial recruitment (10^6; Model 4)	$R_{y=1997} \sim$ U(10, 1000)	
Natural mortality (yr^{-1})	$\bar{M} \sim$ U(0.5, 2)	Miller et al. 2011; Murphy et al. 2007
Fishing mortality (yr^{-1})	$F_y \sim$ U(0.001, 3)	Eggleston et al. 2004
Selectivity for recruits	$g_{R,\,s} \sim$ U(0, 0.6)	Rudershausen and Hightower 2016
Ricker productivity parameter (#offspring per spawner; Model 4)	$\alpha \sim$ U(1, 15)	Eggleston et al. 2004; VanderKooy 2013
Ricker density-dependence parameter (Model 4)	β = 0.005	Eggleston et al. 2004; VanderKooy 2013
Standard deviation of process errors	σ_N, $\sigma_R \sim$ U(0.001, 10)	
Standard deviation of observation errors	$\sigma_{CN,\,s}$, $\sigma_{CR,s} \sim$ U(0.001, 10) $\sigma_{sp,\,j}$, $\sigma_{IN,\,s,\,j}$, $\sigma_{IR,\,s,\,j} \sim$ U(0.001, 10)	
Standard deviation of natural mortality error	σ_{MM}, $\sigma_M \sim$ U(0.001, 1)	

Table 3.2. Priors for catchability (q; 10^{-6}). U denotes uniform distribution. Derived from catch and abundance index data by assuming catch is the lower bound for population size and 100 x catch is the upper bound. Set minimum index /(100 x maximum catch) as lower bound, and maximum index /minimum catch as upper bound.

Abundance index	Priors
P120 male recruits	U(0.0001, 4)
P195 male recruits June	U(0.0001, 58)
P195 male recruits September	U(0.0001, 13)
P120 female recruits	U(0.0001, 8)
P195 female recruits June	U(0.0001, 202)
P195 female recruits September	U(0.0001, 32)
P100 male fully recruited summer	U(0.0001, 0.5)
P100 male fully recruited fall	U(0.0001, 0.5)
P195 male fully recruited June	U(0.0001, 0.5)
P195 male fully recruited September	U(0.0001, 0.5)
P100 female fully recruited summer	U(0.0001, 0.1)
P100 female fully recruited fall	U(0.0001, 1)
P195 female fully recruited June	U(0.0001, 1)
P195 female fully recruited September	U(0.0001, 0.5)
P195 spawner	U(0.0001, 1)
SEAMAP spawner	U(0.0001, 1.5)

Table 3.3. Candidate models.

Model	Features
Model 1 (baseline)	Sex- and stage-specific natural mortality
	Recruitment free parameter to estimate (lognormal distribution)
	Time-constant catchability
	All abundance indices
	Initial year when catch data start (1995)
	Sex-specific recruits selectivity to estimate
Model 2	Same as Model 1 except a constant natural mortality to estimate
Model 3	Same as Model 1 except a constant natural mortality to input
Model 4	Same as Model 1 except recruitment follows a Ricker model

9 FIGURES

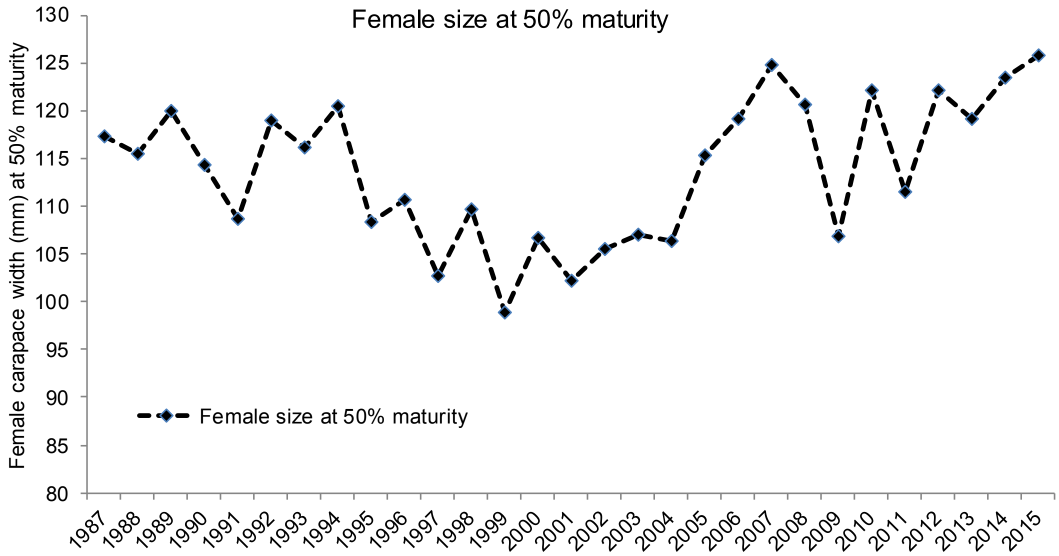


Figure 1.1. Annual carapace width at 50% maturity for female blue crabs collected in several NCDMF sampling programs and North Carolina water bodies, 1987-2015.

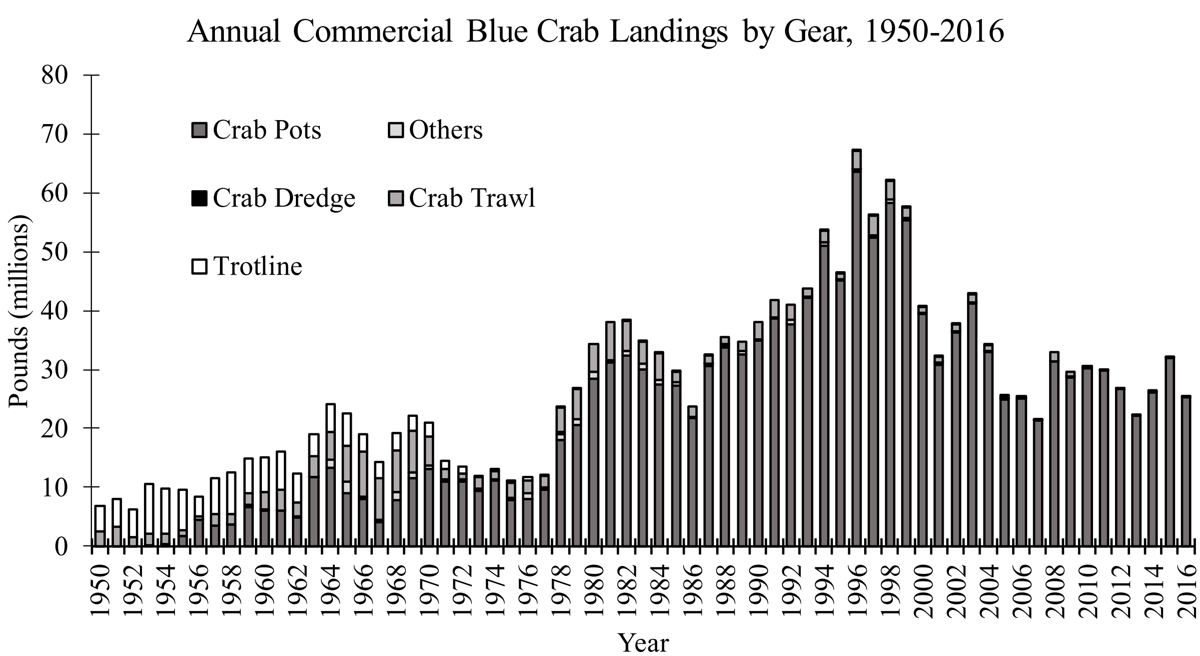


Figure 1.2. Annual commercial fishery landings of blue crabs in North Carolina, by major gear, 1950–2016.

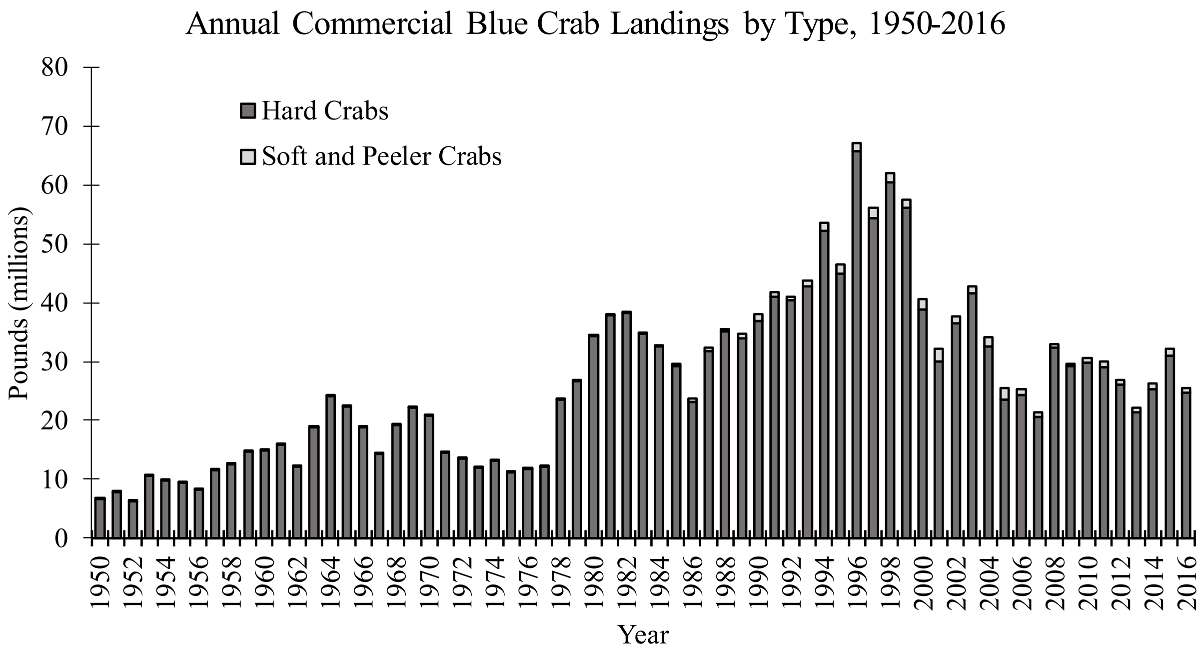


Figure 1.3. Annual commercial fishery landings of blue crabs in North Carolina, by crab type, 1950–2016.

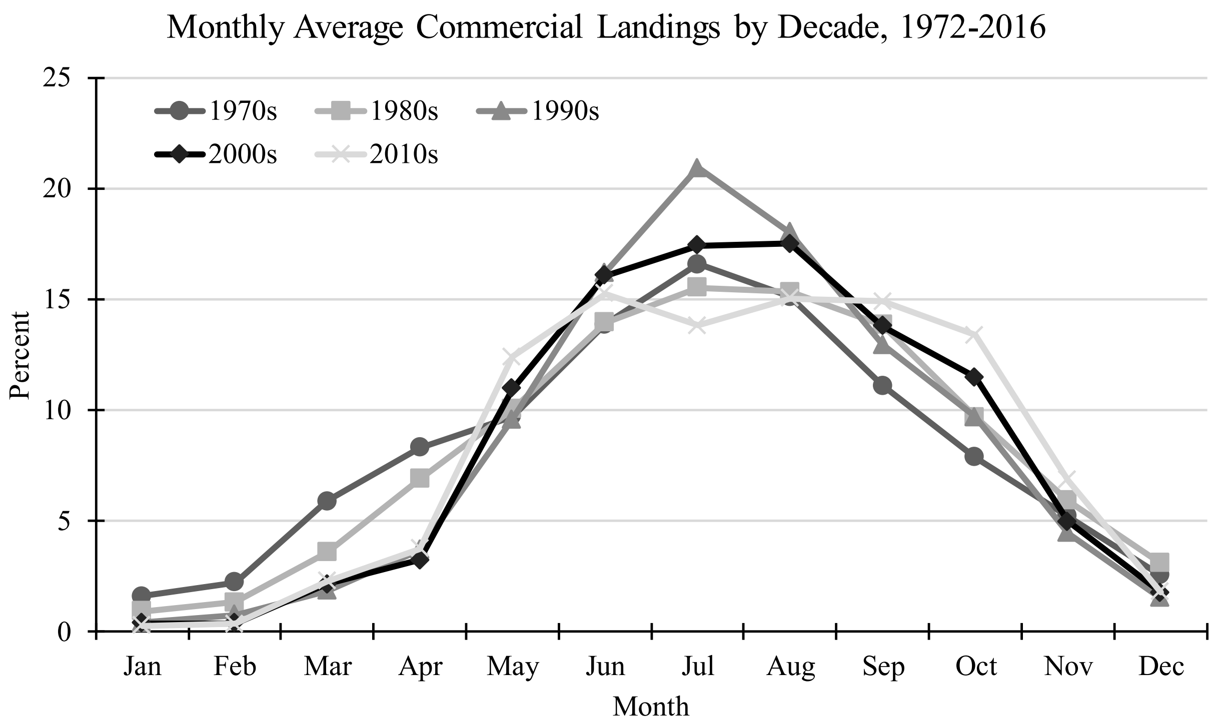


Figure 1.4. Average percent of blue crab commercial landings among months, by decade, 1972–2016.

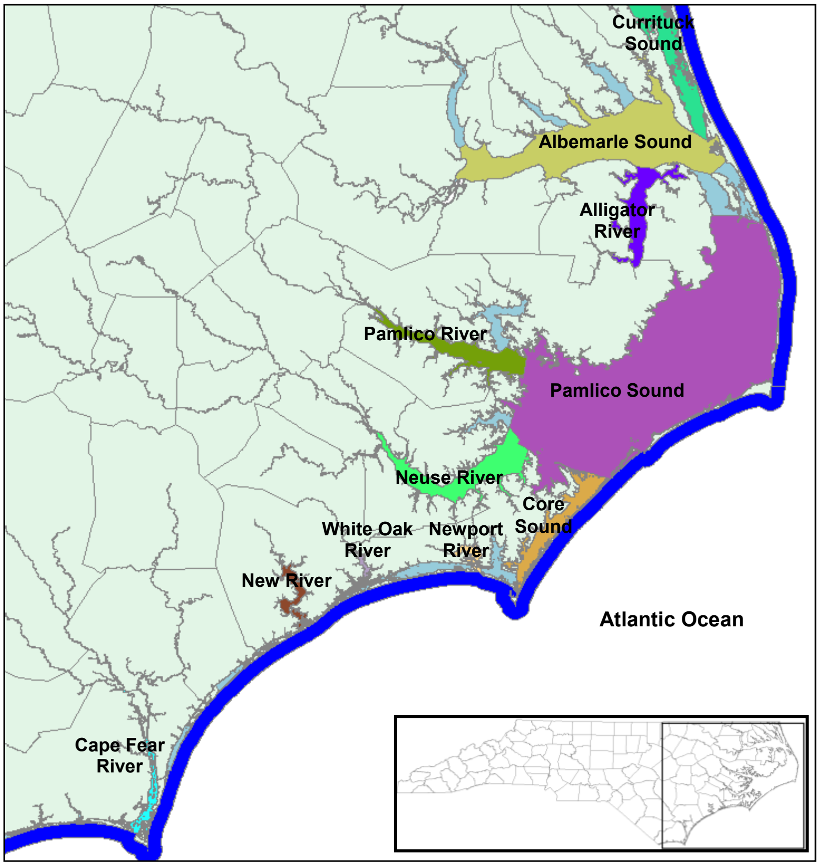


Figure 1.5. Major water bodies within and around North Carolina. The dark blue area represents the extent of the state's coastal fishing waters, which extend to three miles offshore.

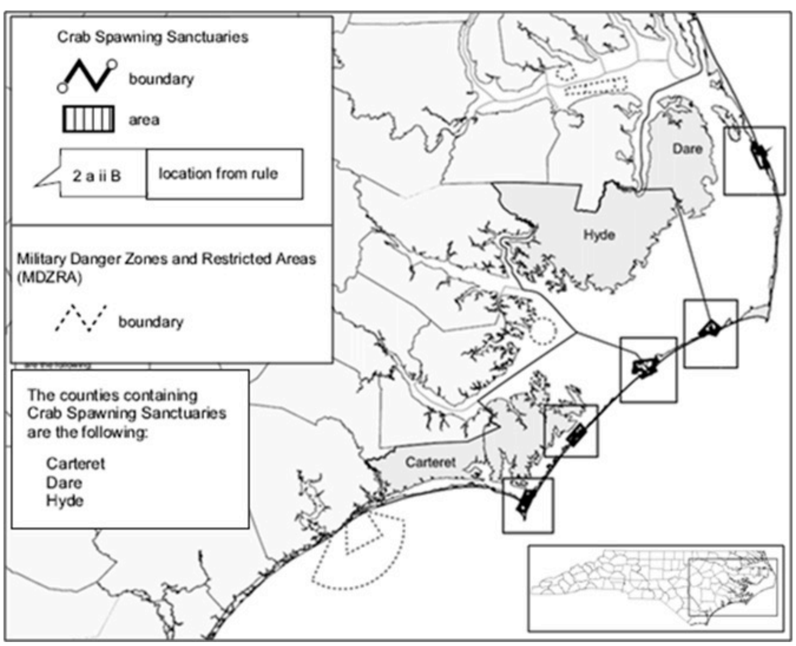


Figure 1.6. General location of blue crab spawning sanctuary areas for the protection of mature female crabs (NCMFC rules 15 NCAC 03L .0205 and 03R .0110).

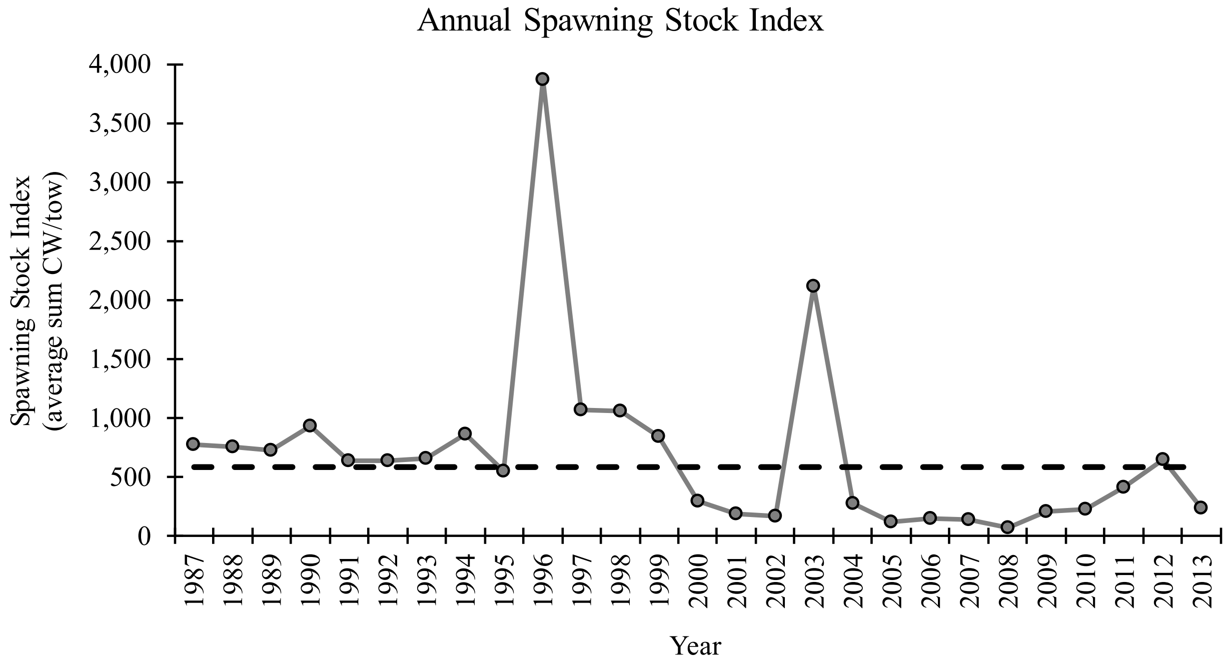


Figure 1.7. Spawning stock index adopted as the management trigger in the 2004 amendment to the North Carolina Blue Crab FMP, 1987-2013. The dashed line represents the lower 90% confidence limit of the reference baseline average (1987–2003). When the spawning stock index falls below this line for two consecutive years, the NCDMF had the proclamation authority to implement spawning stock protection measures.

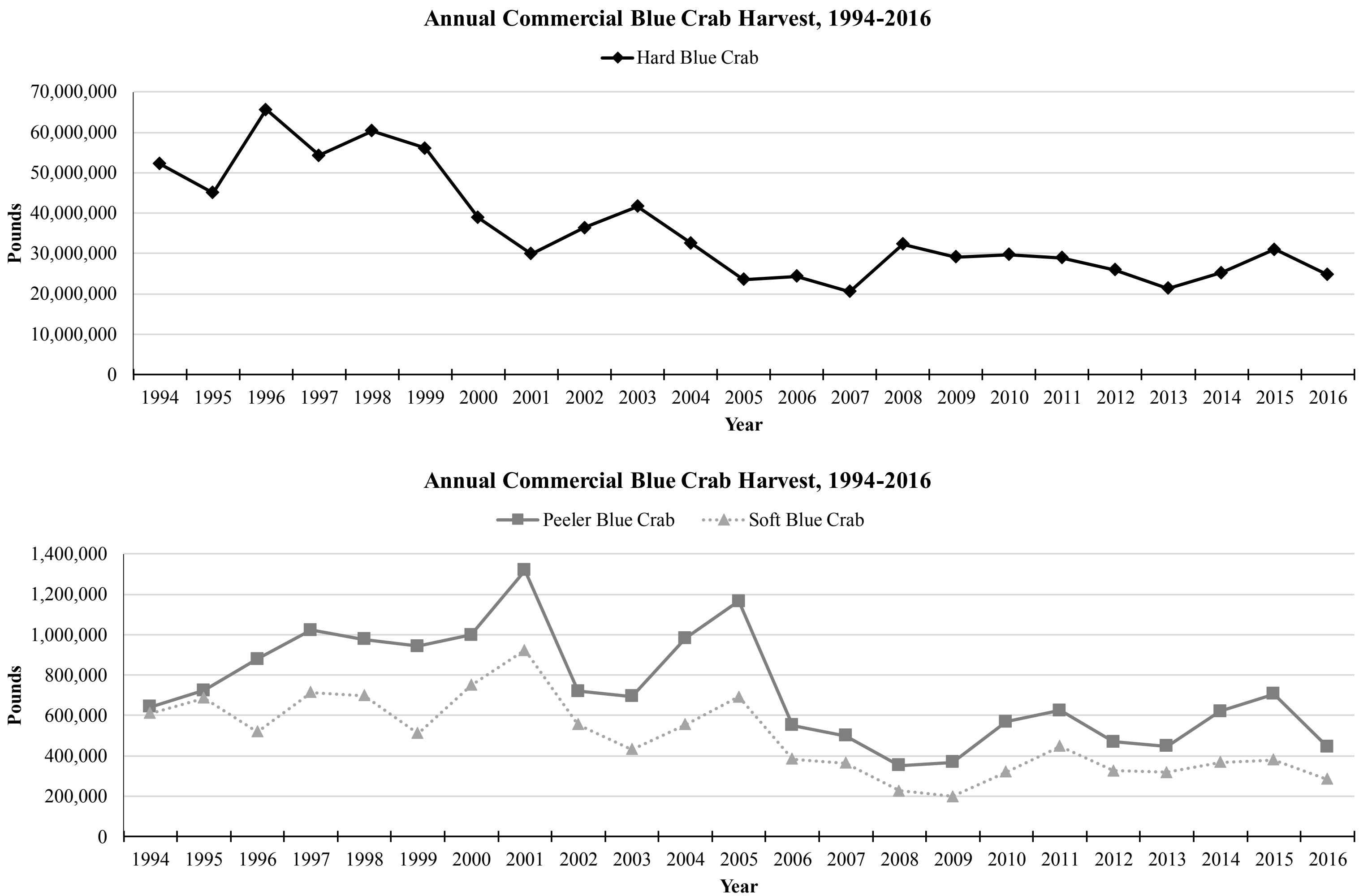
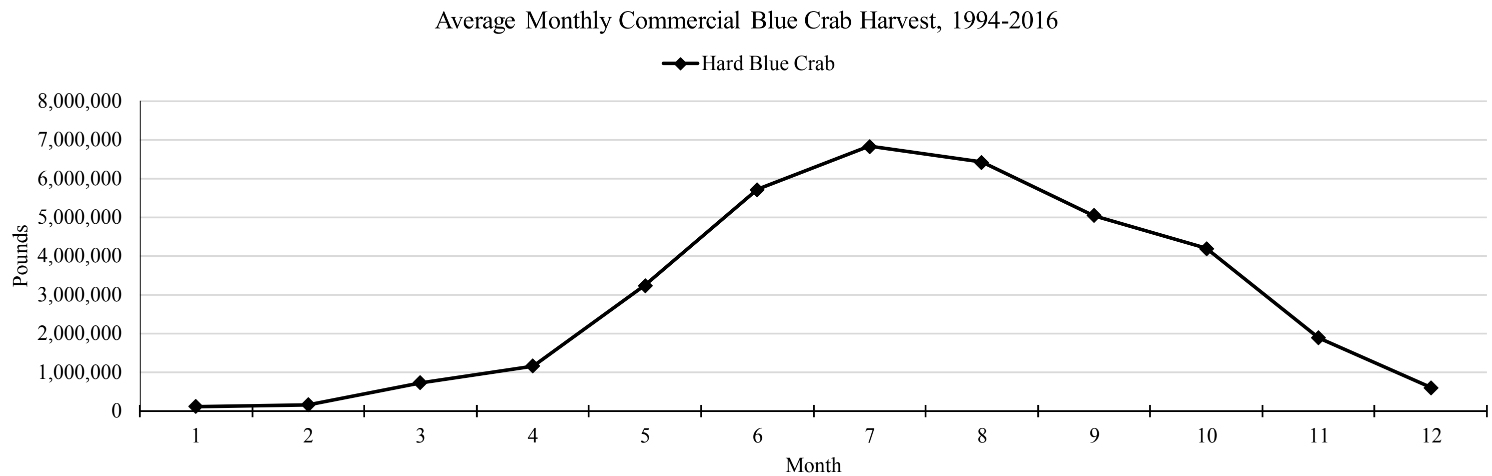


Figure 2.1. Commercial hard, peeler and soft blue crab landings, 1994–2016.



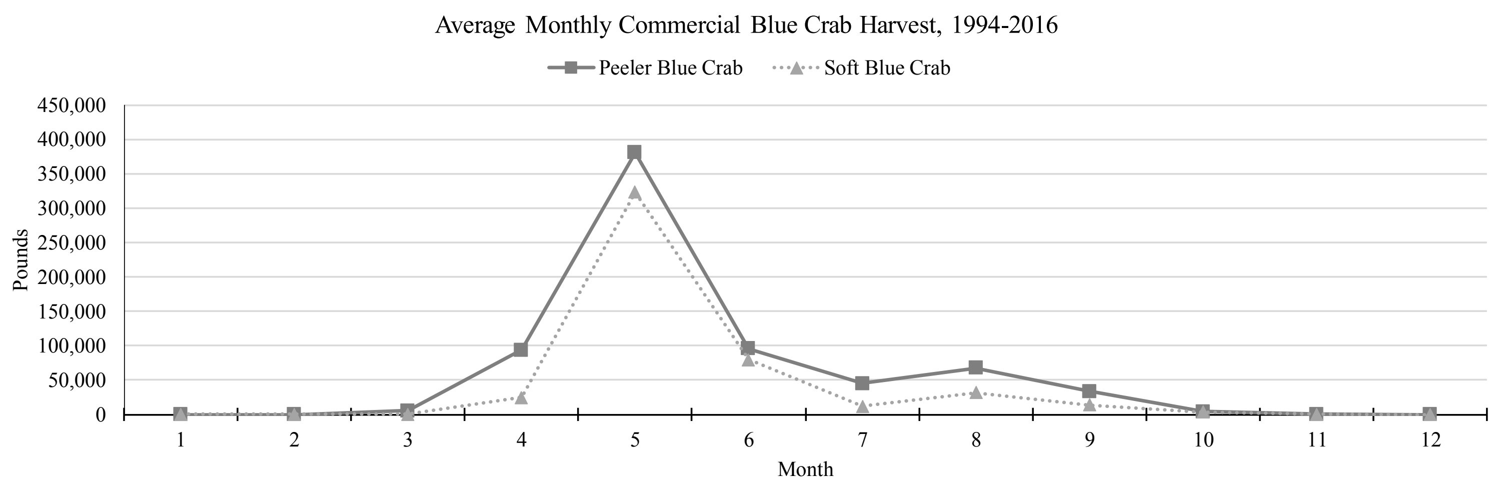
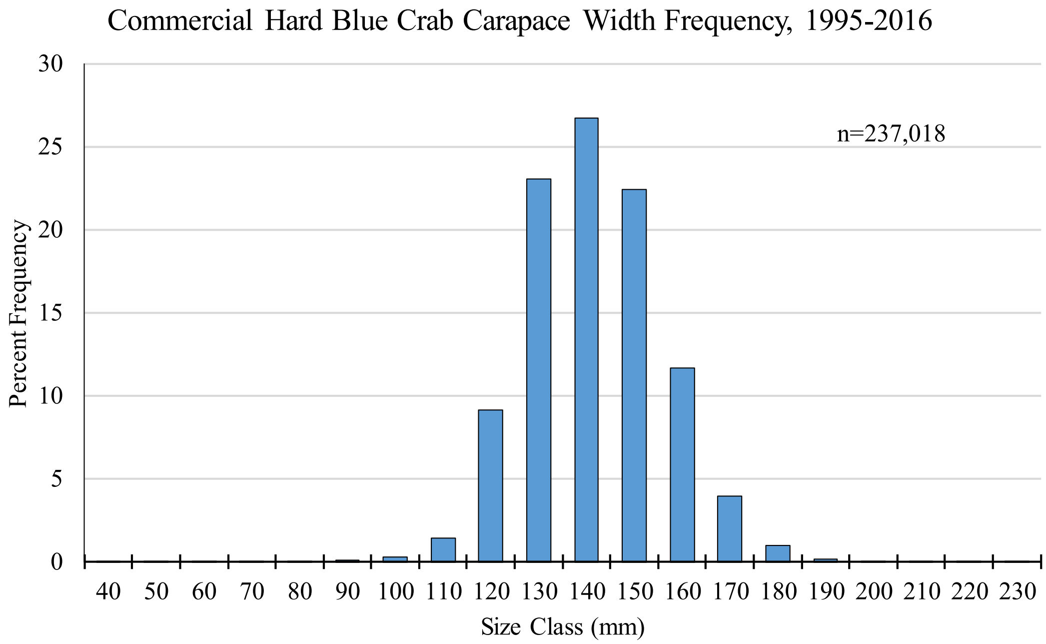


Figure 2.2. Average annual commercial landings of blue crab by type and by month, 1994-2016.



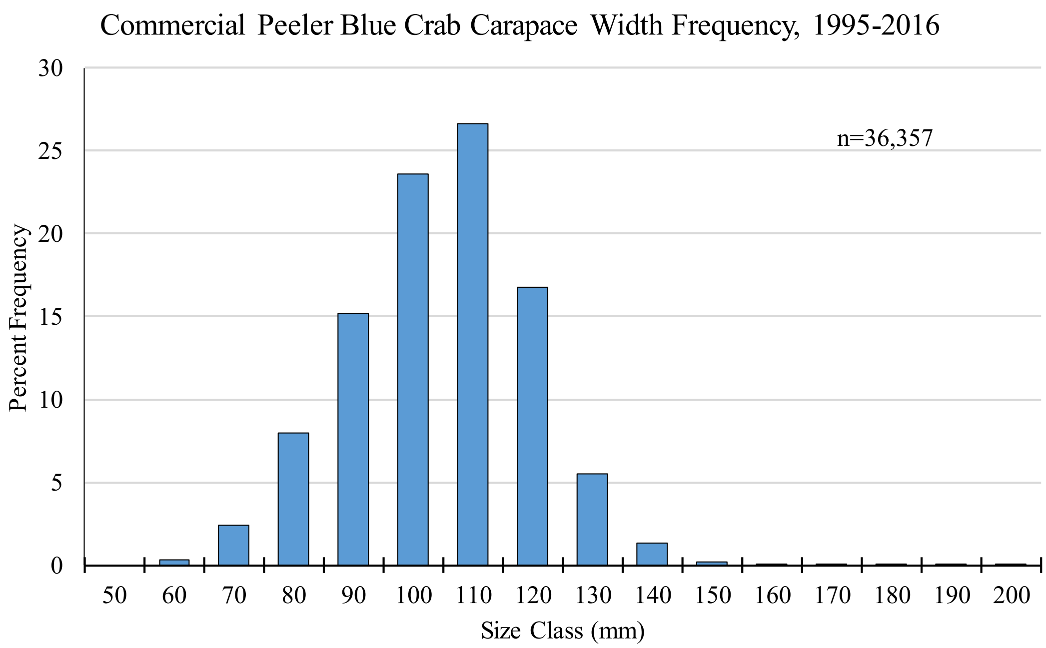


Figure 2.3. Carapace width frequency (10 mm bins) of hard and peeler blue crabs landed by commercial fisheries in North Carolina, 1995-2016. Note: no measurements taken for soft blue crabs.

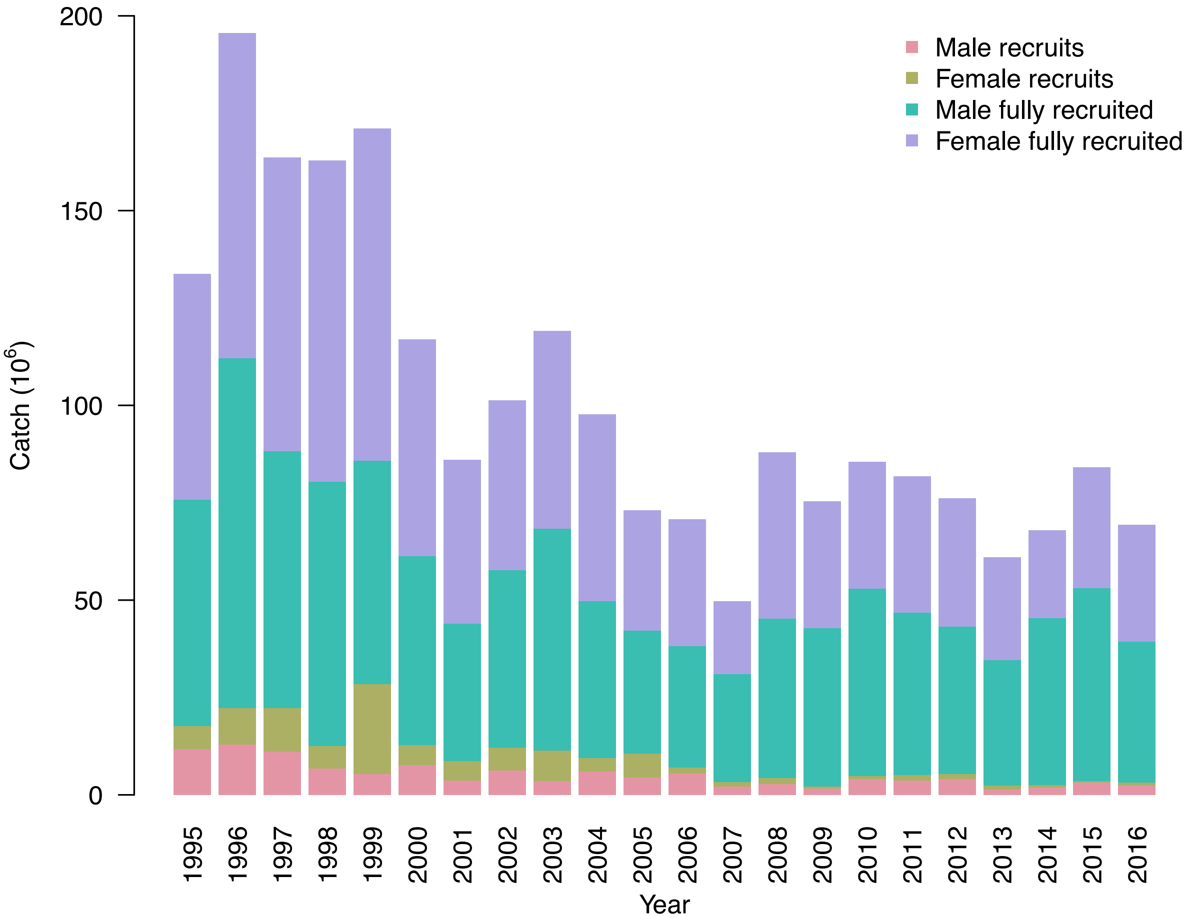


Figure 2.4. Commercial catch data of North Carolina blue crab by sex and stage (< 127 mm CW as recruits and ≥ 127 mm CW as fully recruited crabs) during 1995-2016.

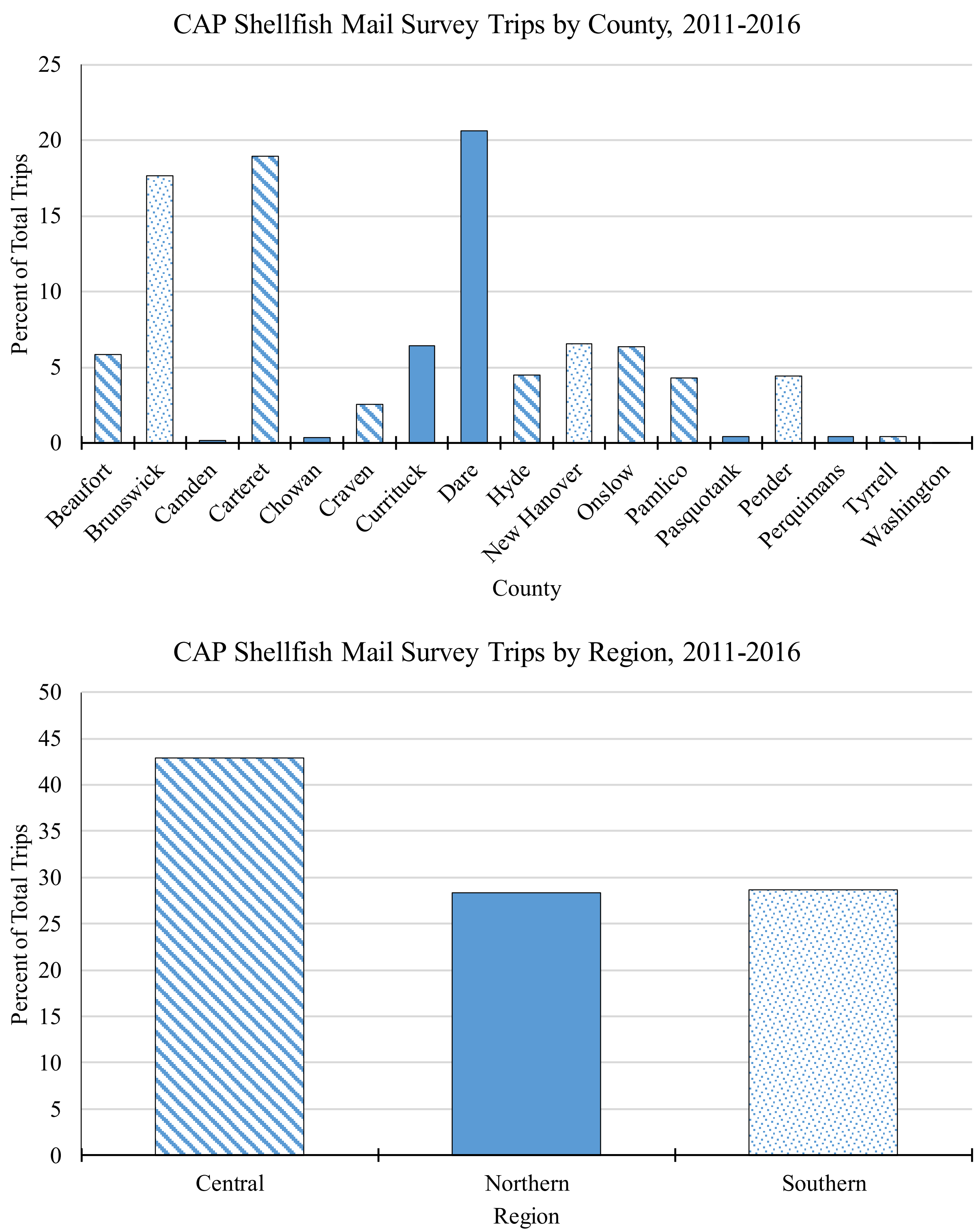


Figure 2.5. Percent crab trips by county and region from CAP shellfish mail survey, 2011-2016.

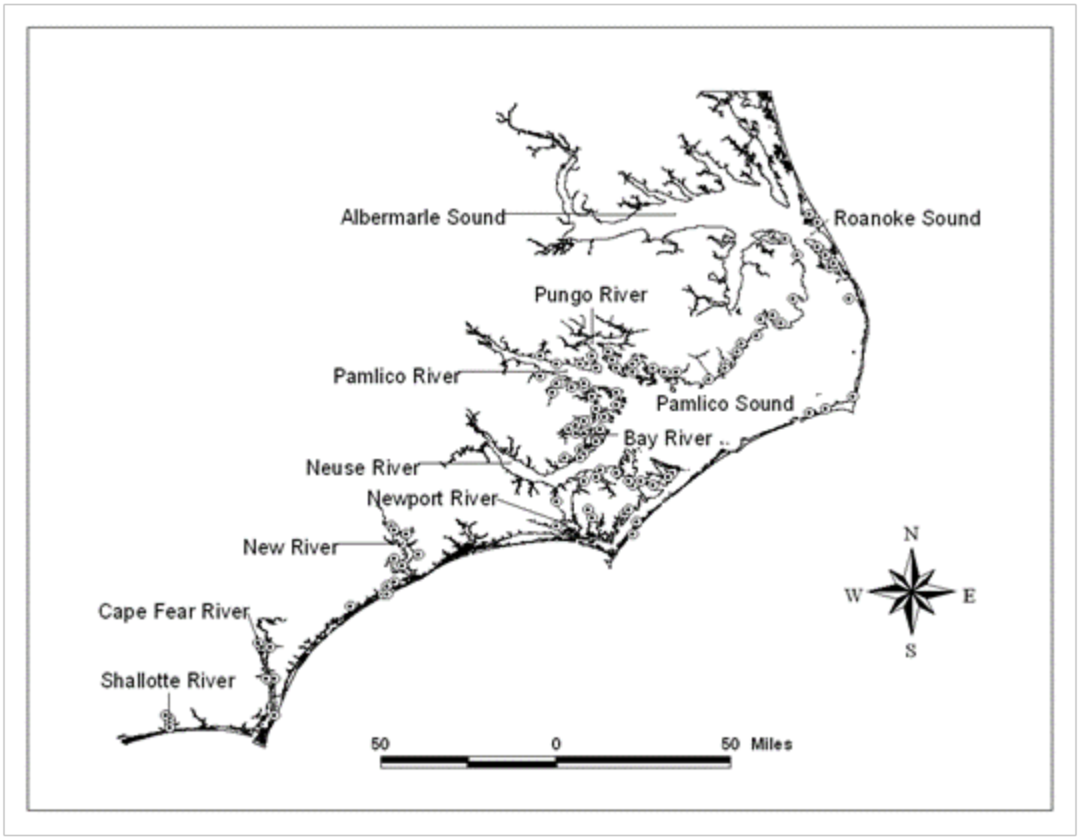
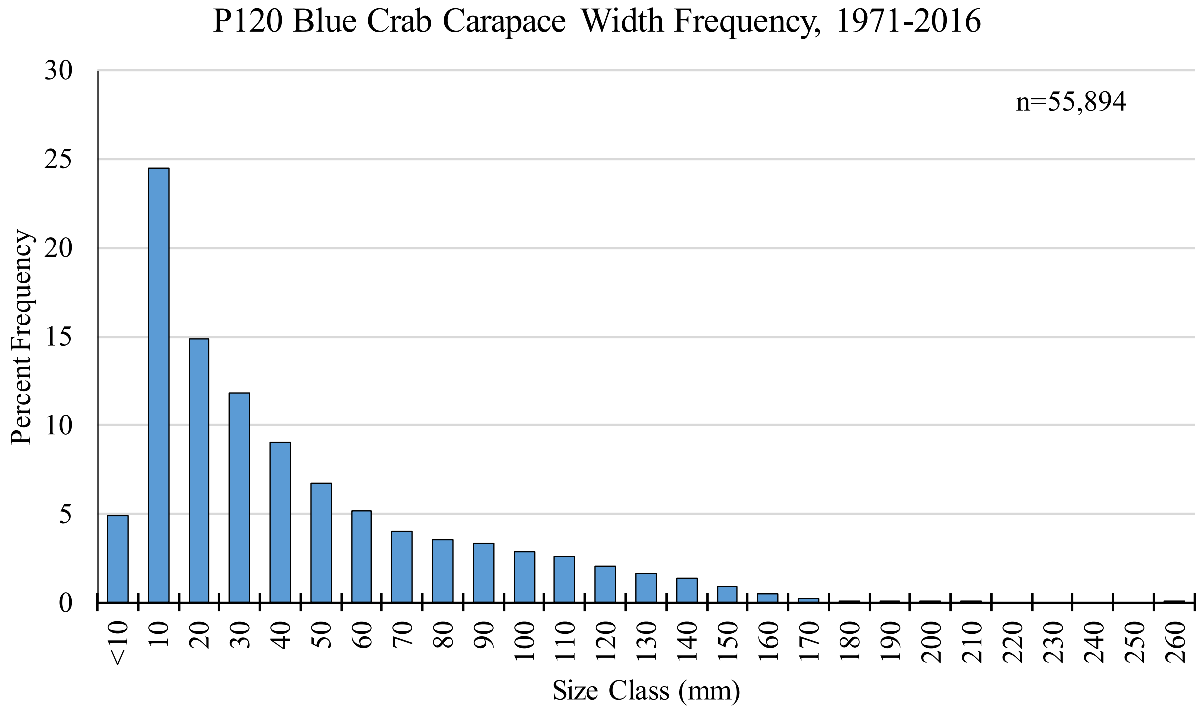


Figure 2.6. Location of all core sample stations in Program 120.



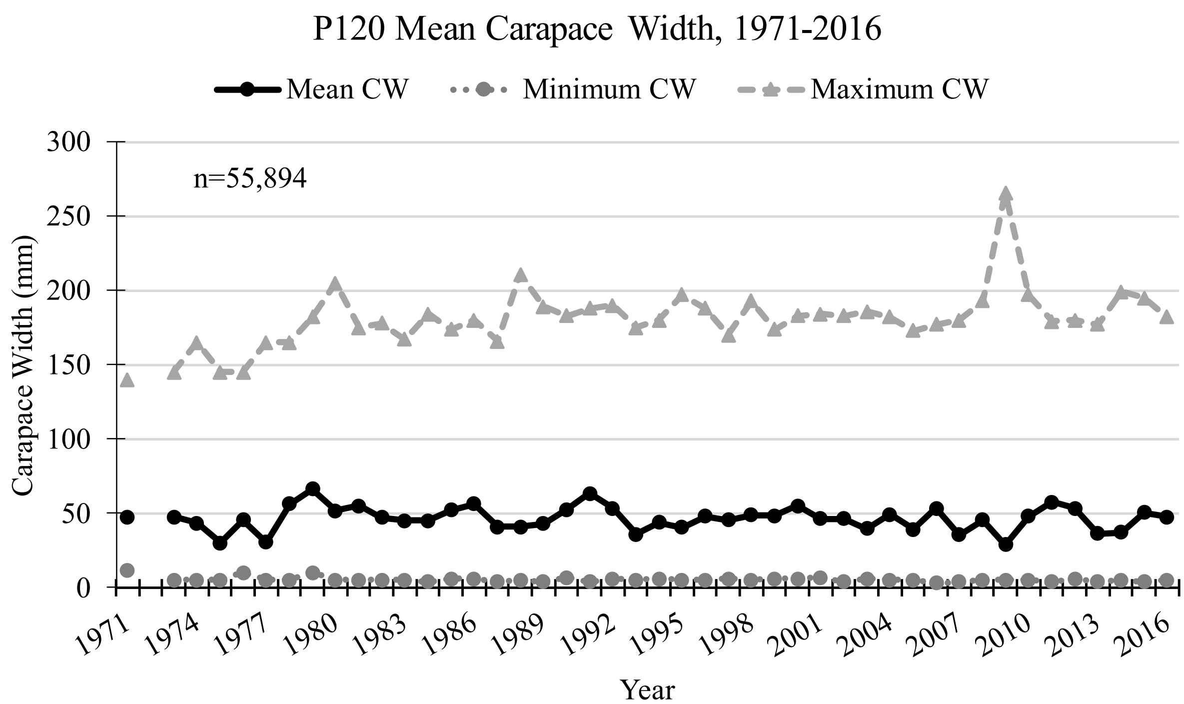


Figure 2.7. Carapace width frequency (10 mm bins), annual mean, minimum, and maximum carapace width (mm) of all blue crab captured in Program 120 core stations in May and June, 1971 – 2016.

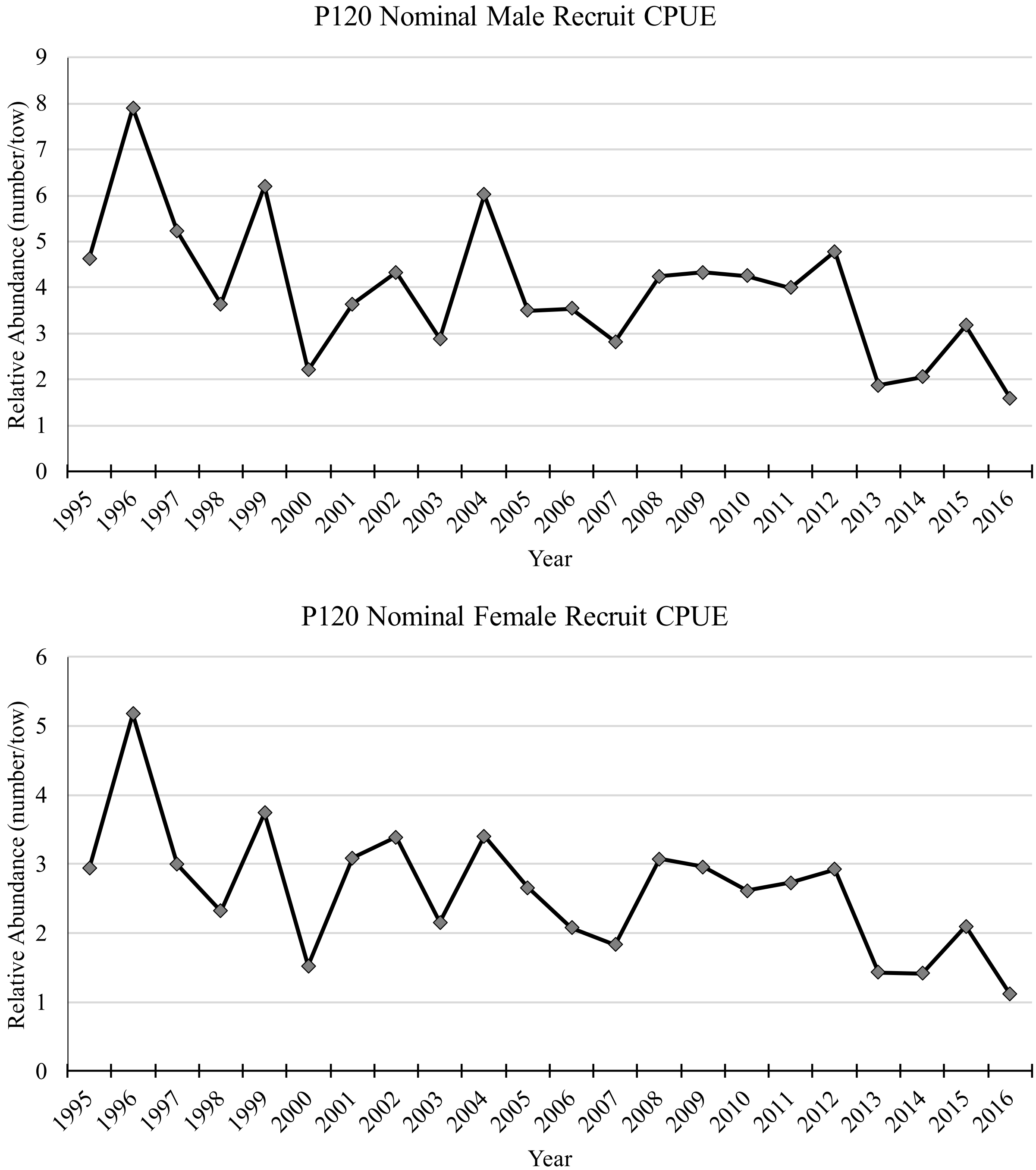


Figure 2.8. Annual nominal catch-per-unit effort (CPUE; number of crab per sample) of recruit (<127 mm CW) blue crabs captured in Program 120 in May and June by sex, 1995 – 2016.

Figure 2.9. Annual standardized catch-per-unit effort (CPUE; number of crab per sample) of recruit (<127 mm CW) blue crabs captured in Program 120 in May and June by sex, 1995 – 2016.

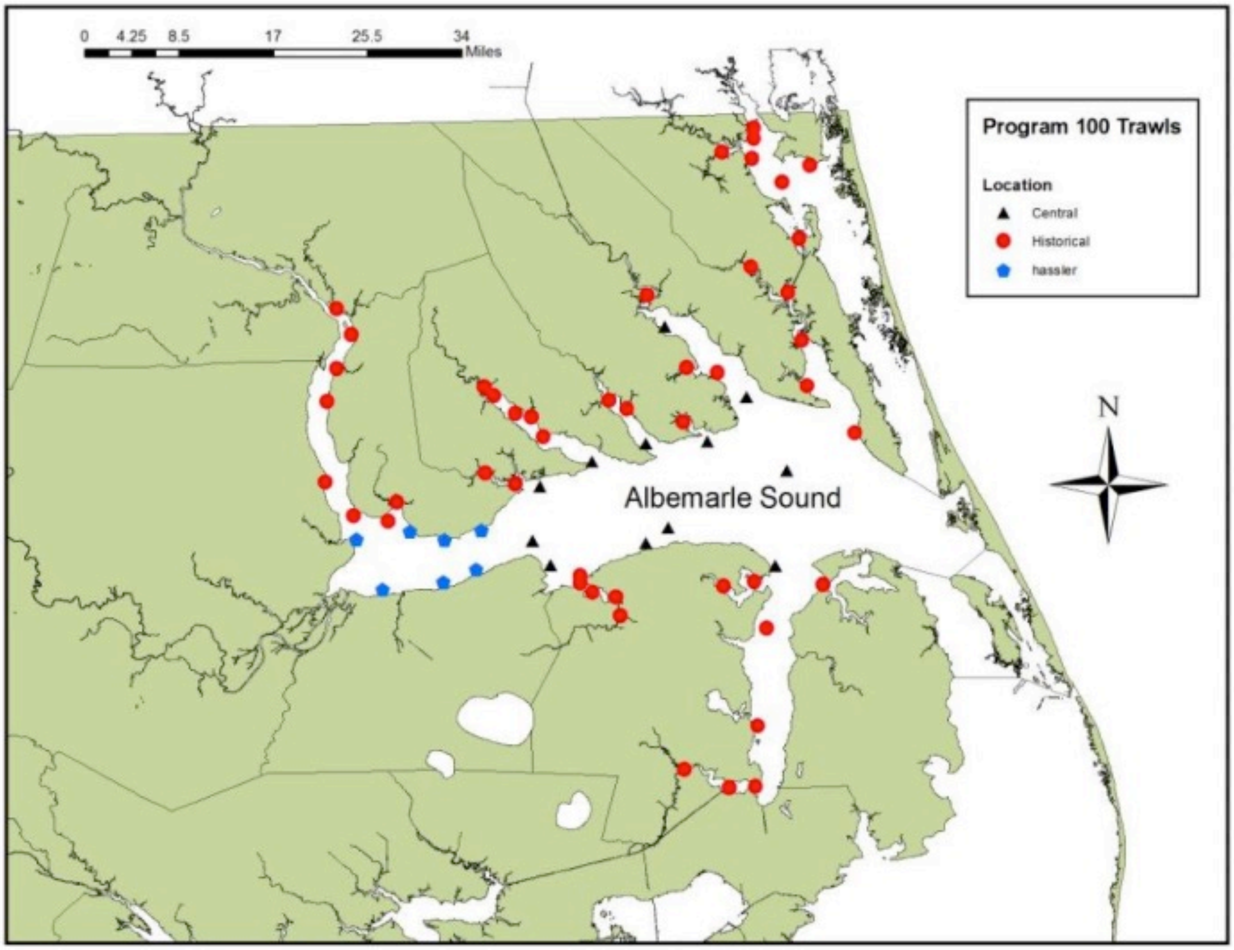
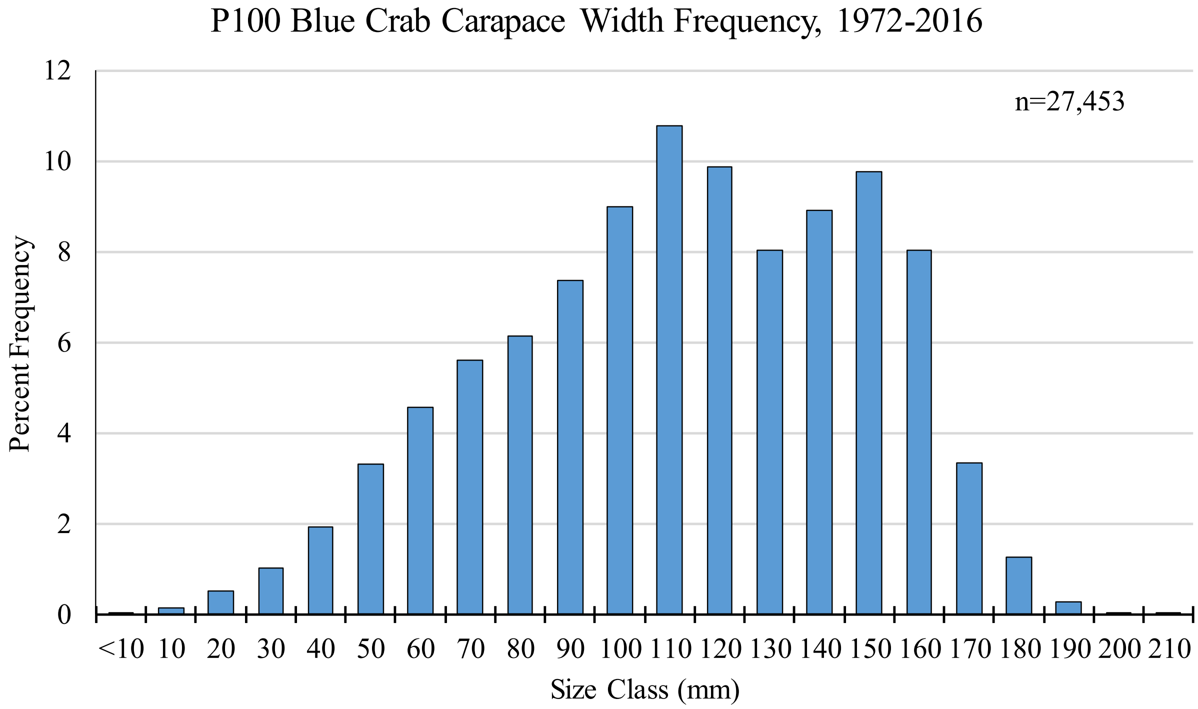


Figure 2.10. Location of all trawl stations in Program 100 by type.



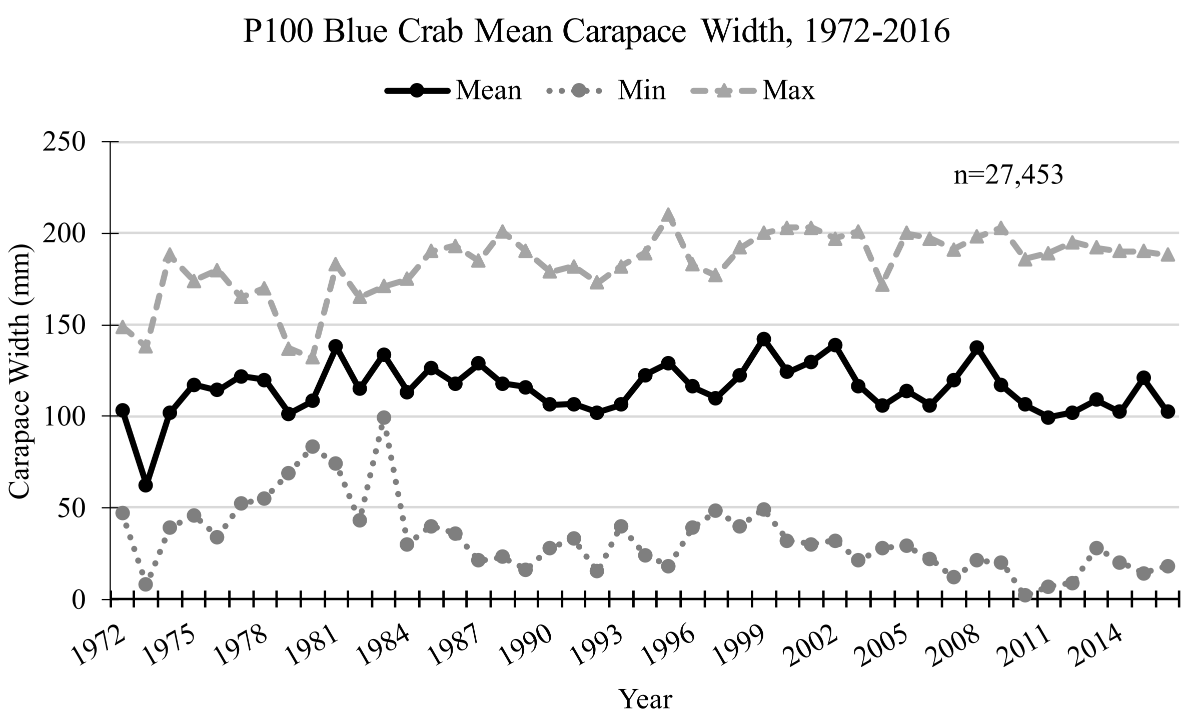
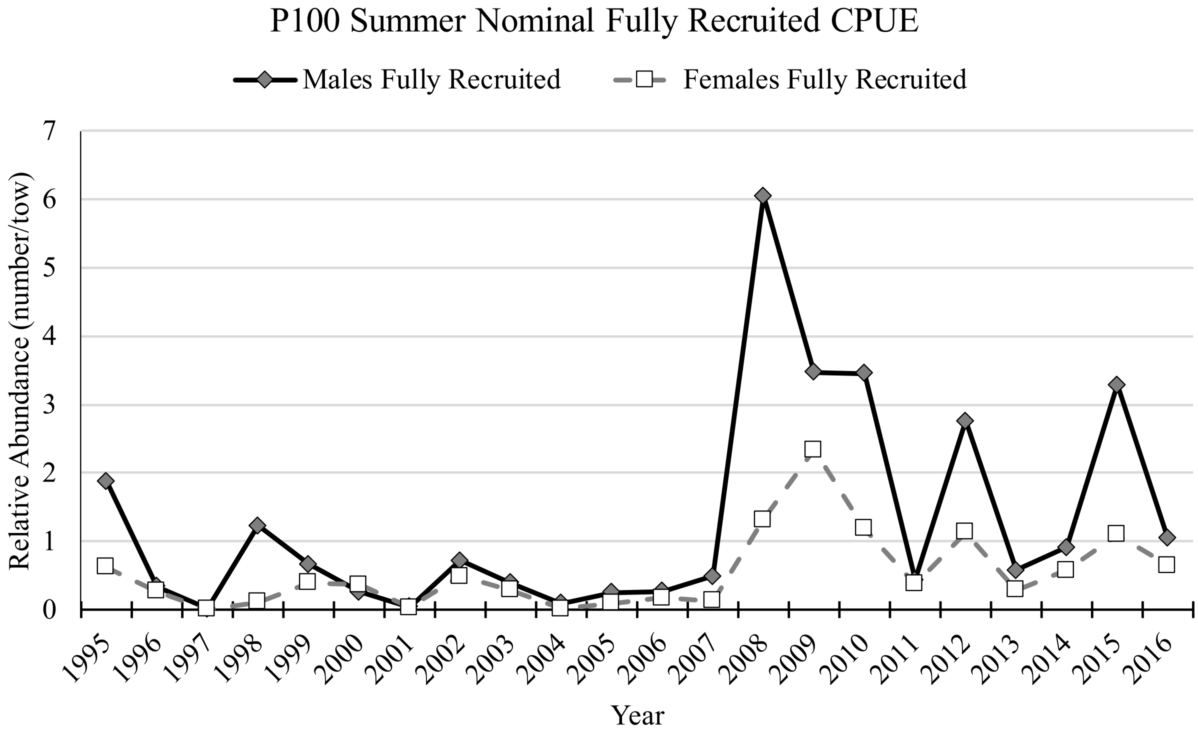


Figure 2.11. Carapace width frequency (10 mm bins), annual mean, minimum, and maximum carapace width (mm) of all blue crabs captured in Program 100 trawl stations, 1972 – 2016.



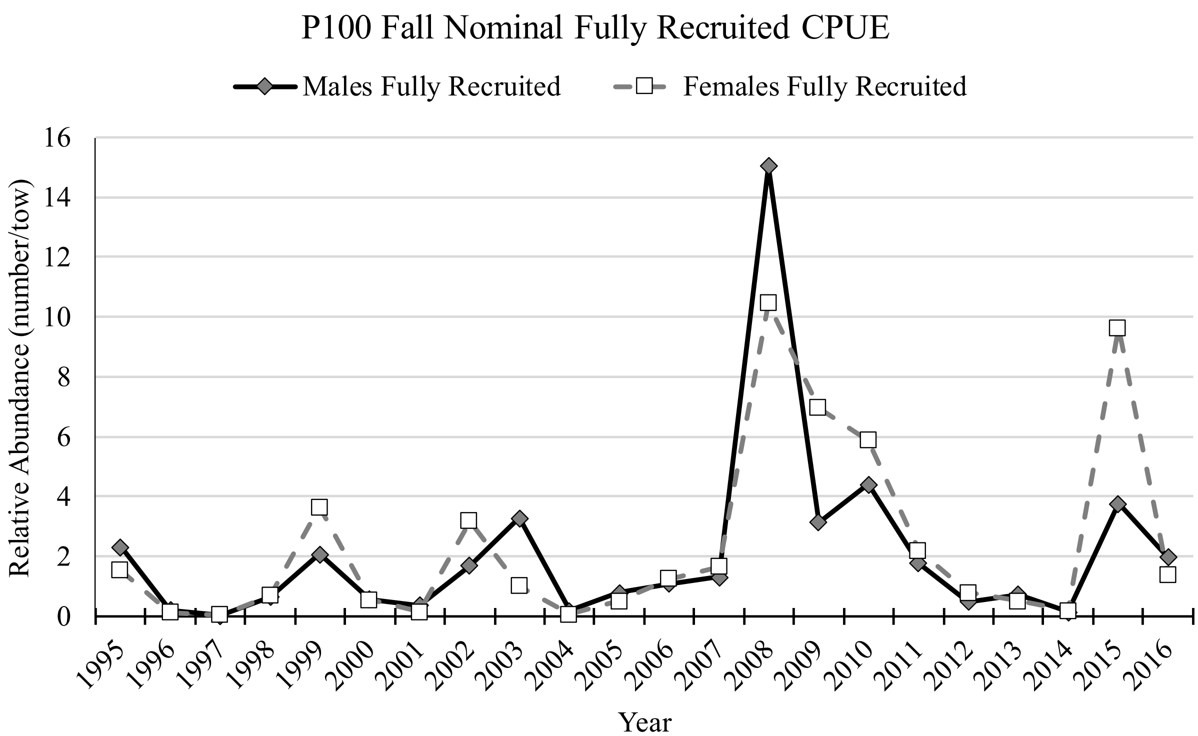


Figure 2.12. Nominal catch-per-unit effort (CPUE; number of crabs per sample) of fully recruited crabs (≥127 mm CW) captured in Program 100 by season and sex, 1995 – 2016.

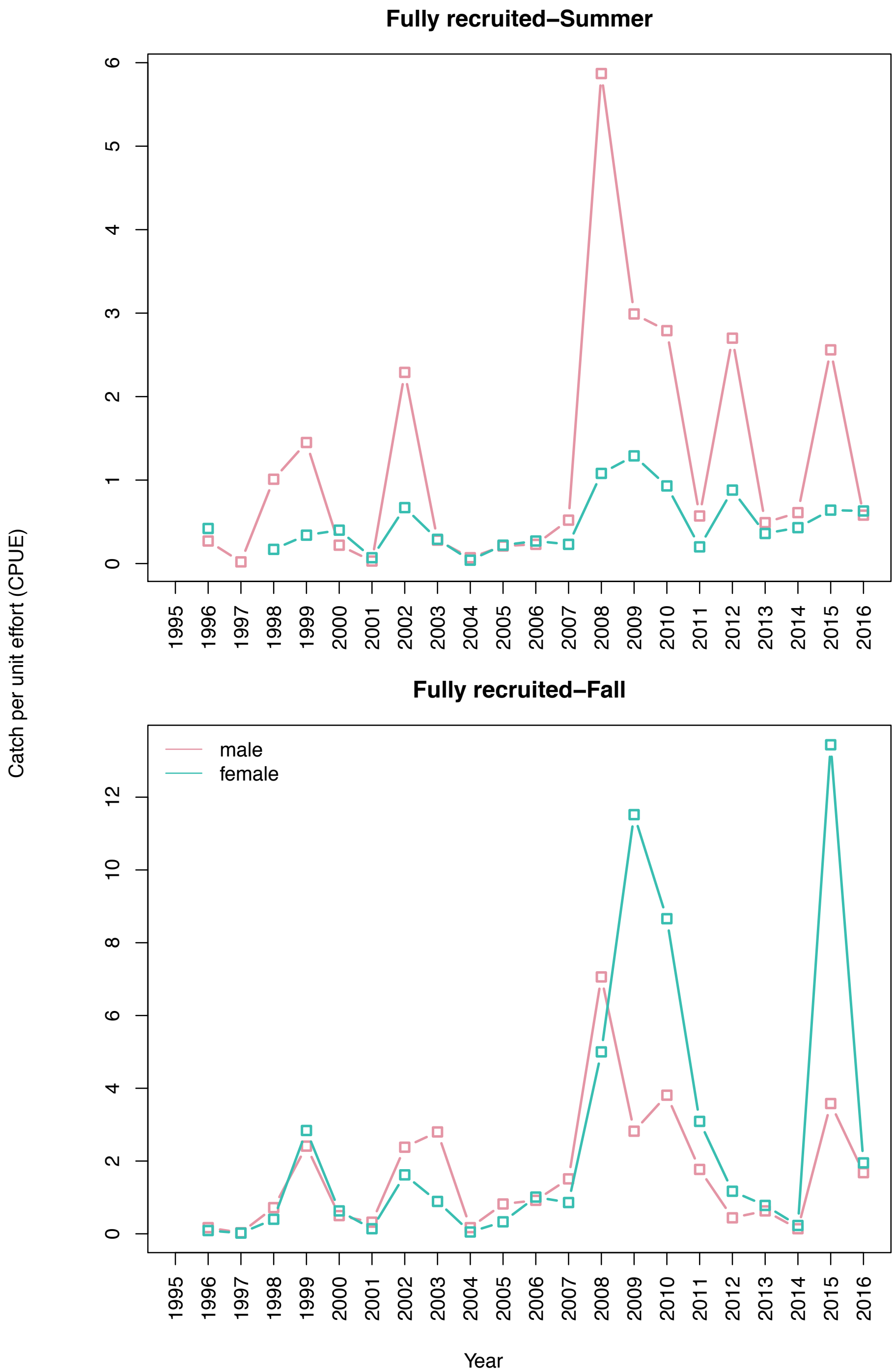


Figure 2.13. Annual standardized catch-per-unit effort (CPUE; number of crabs per sample) of fully recruited crabs (≥127 mm CW) captured in Program 100 by season and sex, 1995 – 2016. Estimated standardized CPUE for female summer indices in 1997 was removed due to large estimated variation.

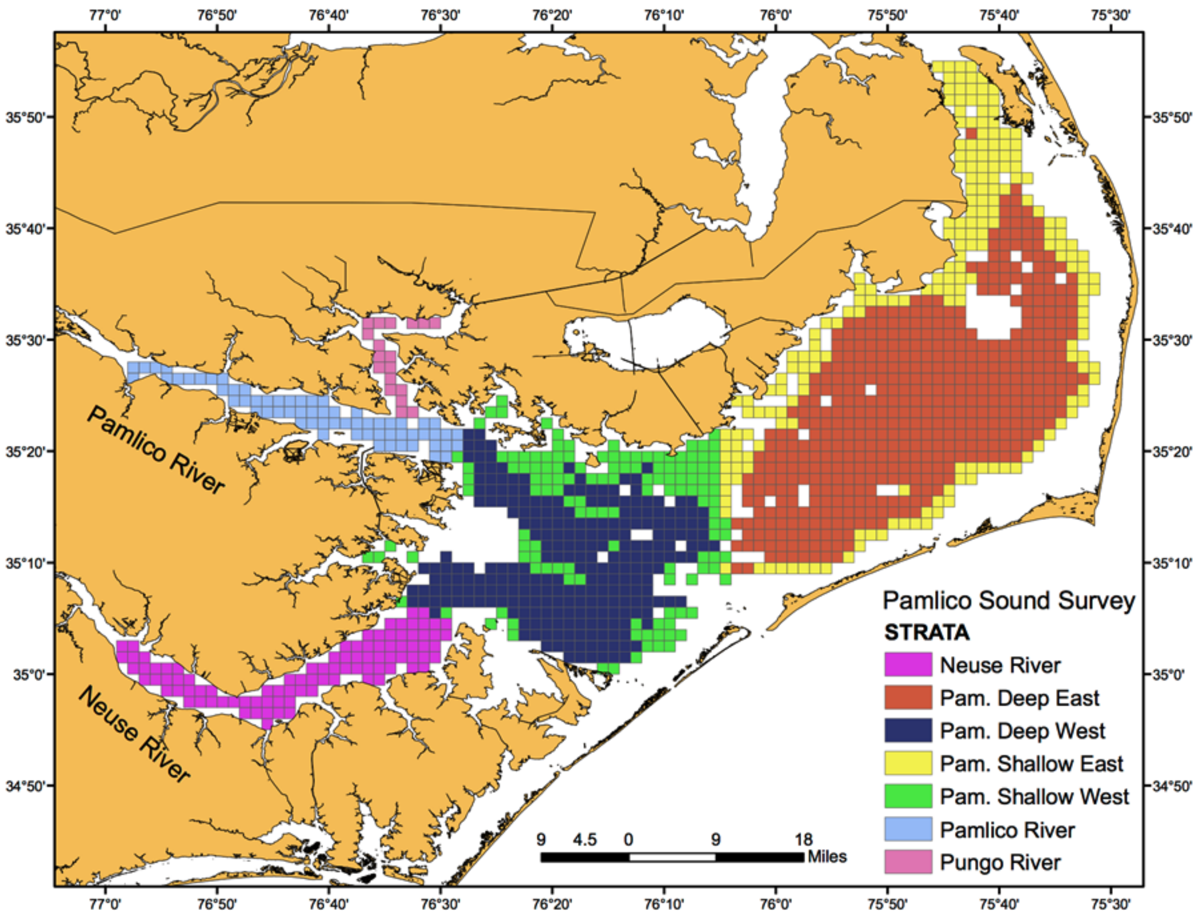
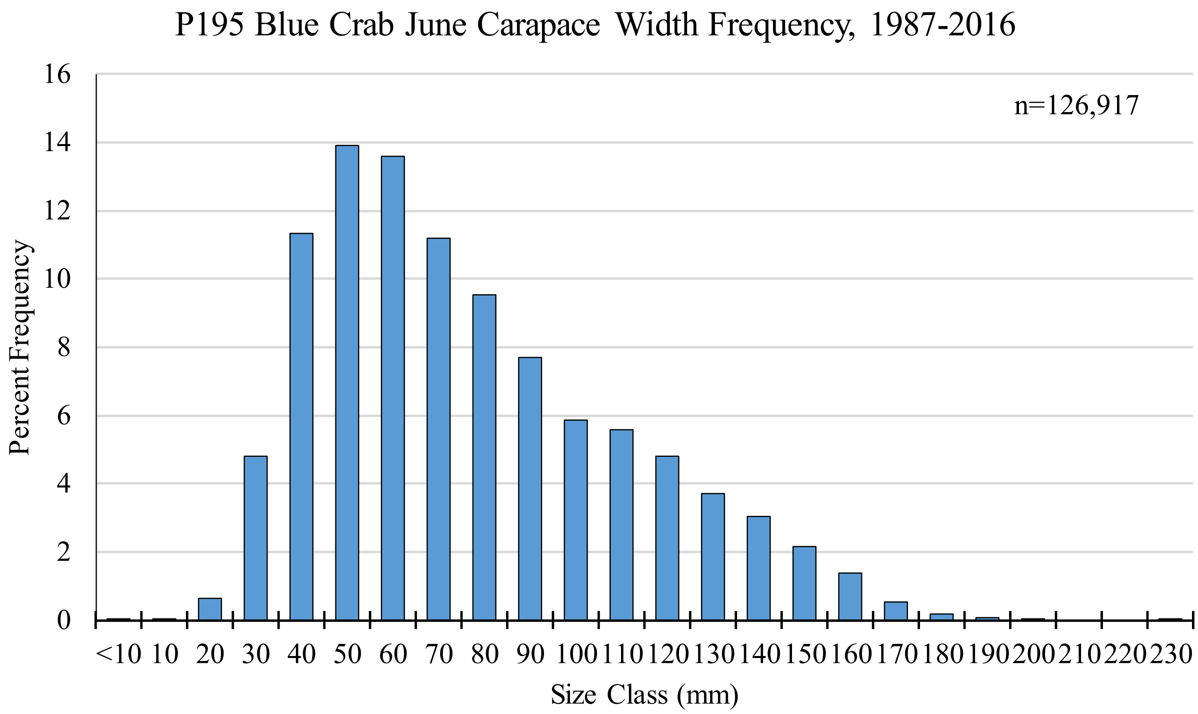


Figure 2.14. Location of all potential sample grids by stratum for the Pamlico Sound Survey (Program 195).



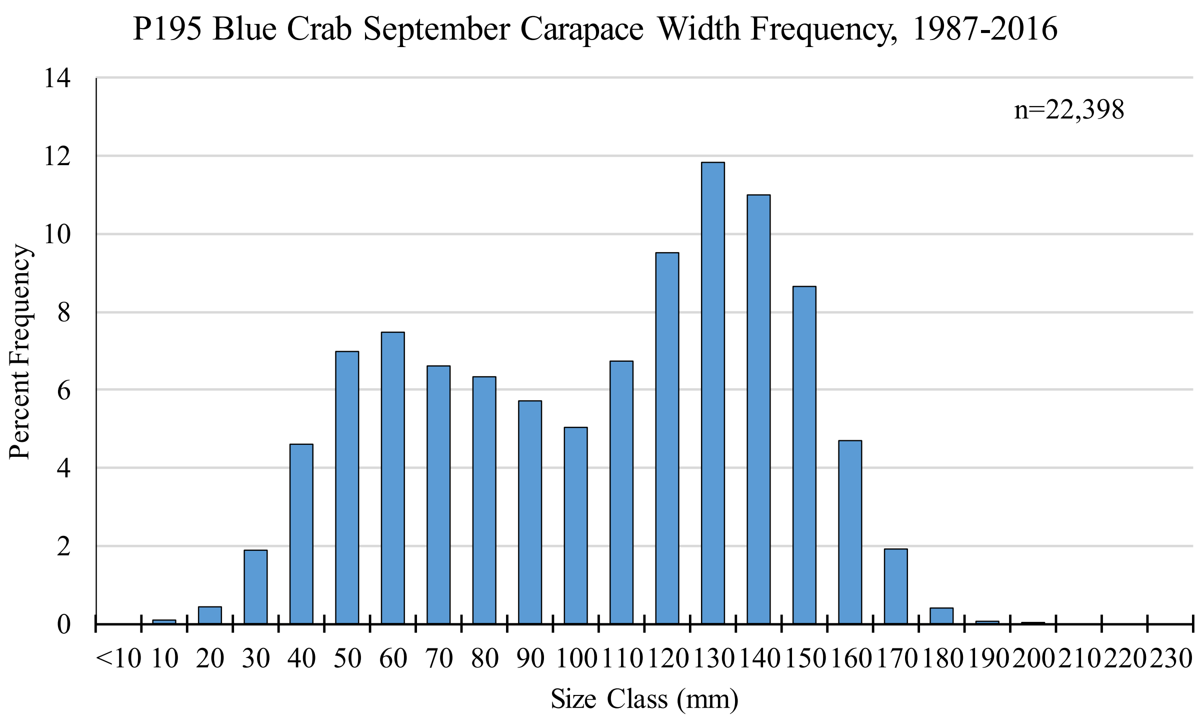
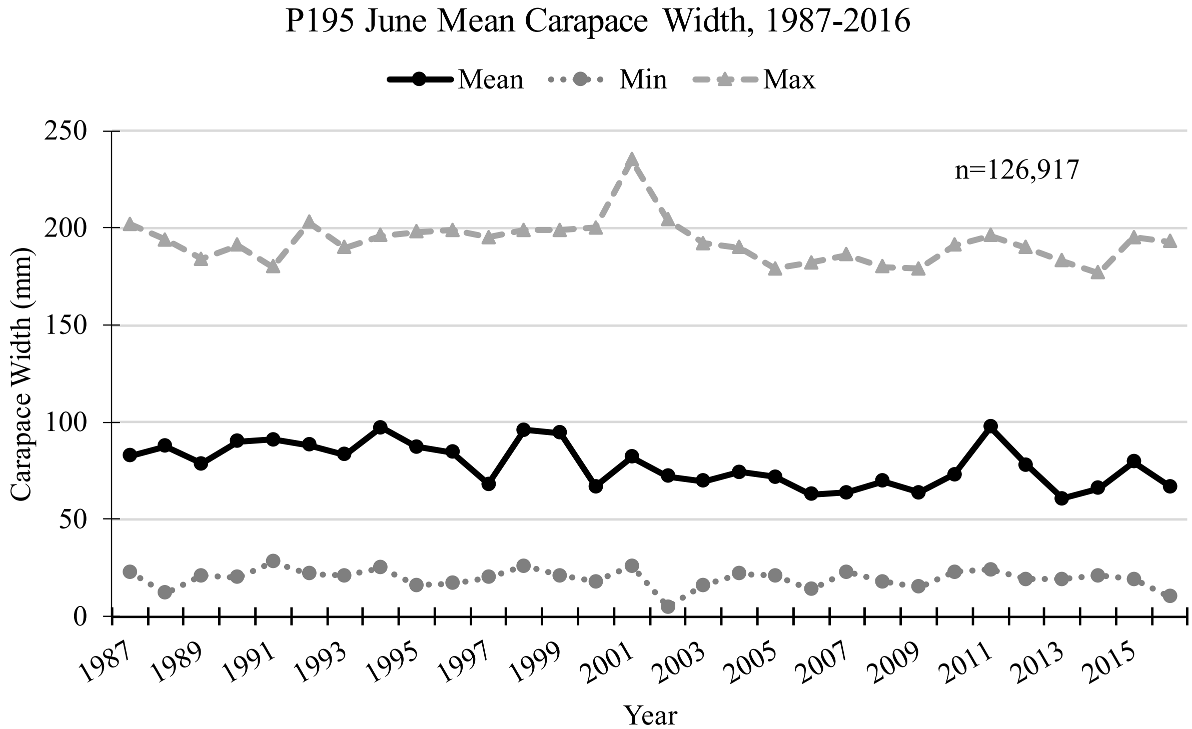


Figure 2.15. Carapace width frequency (10 mm bins) of blue crab captured in program 195 by month, 1987 – 2016 all strata combined.



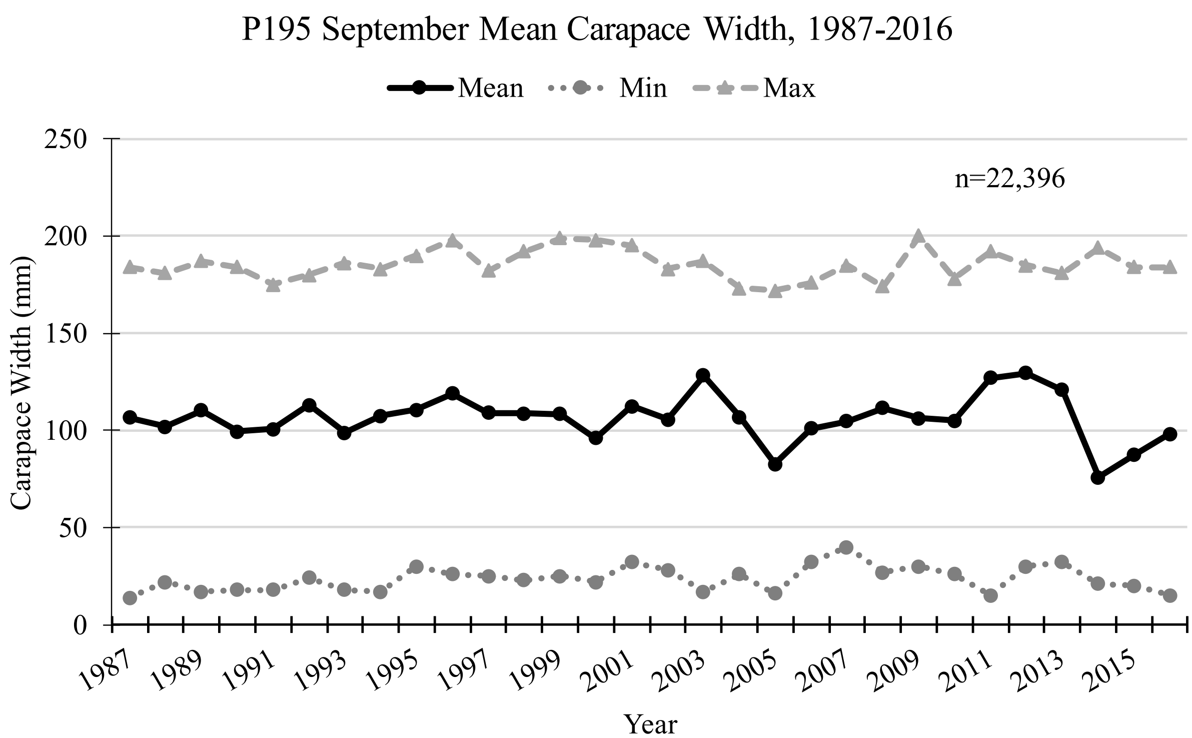
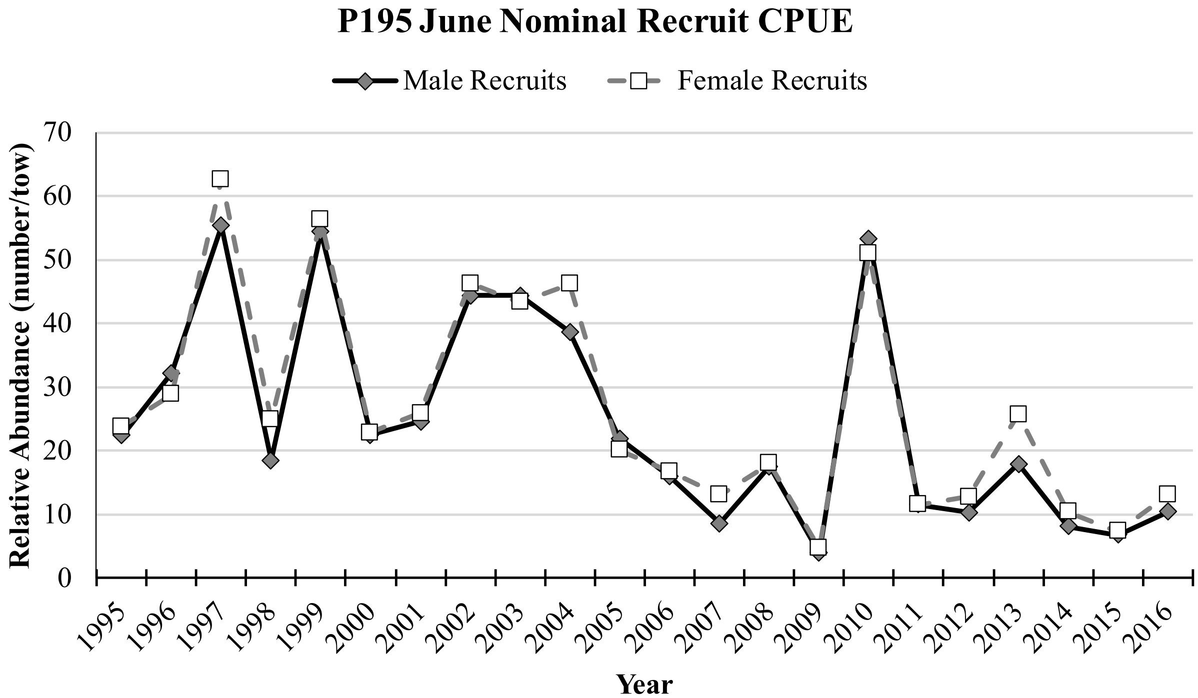


Figure 2.16. Annual mean, minimum, and maximum carapace width (mm) of blue crab captured in Program 195, 1987 – 2016.



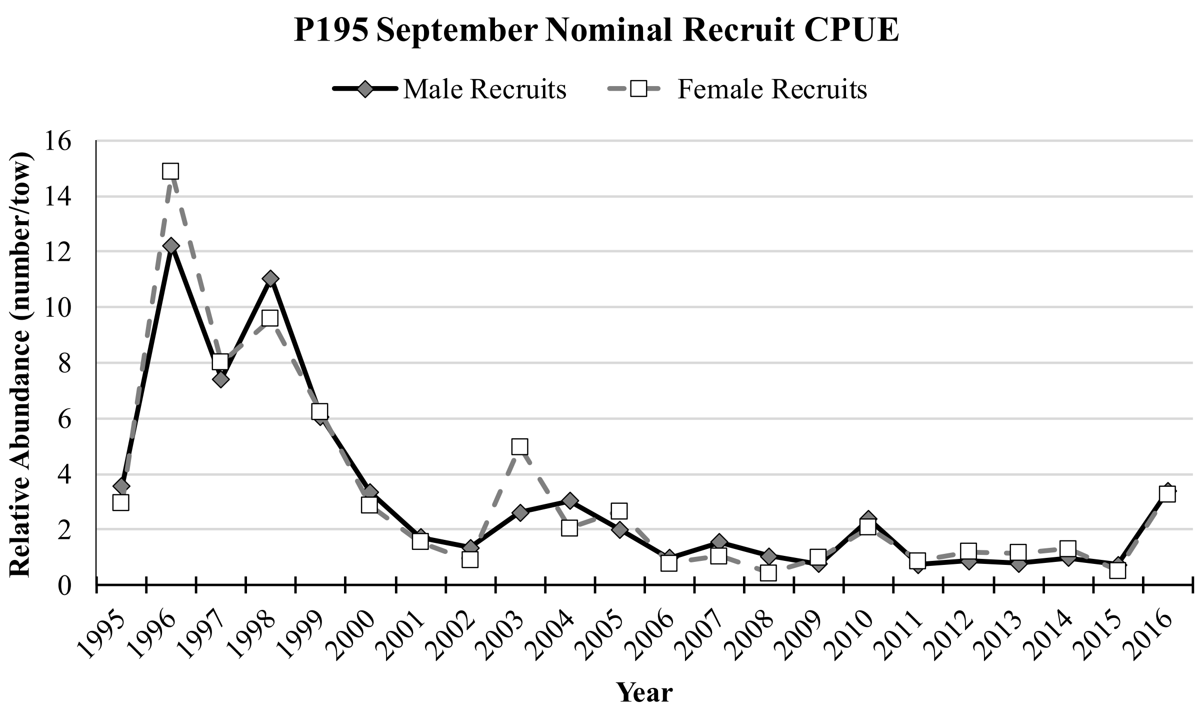
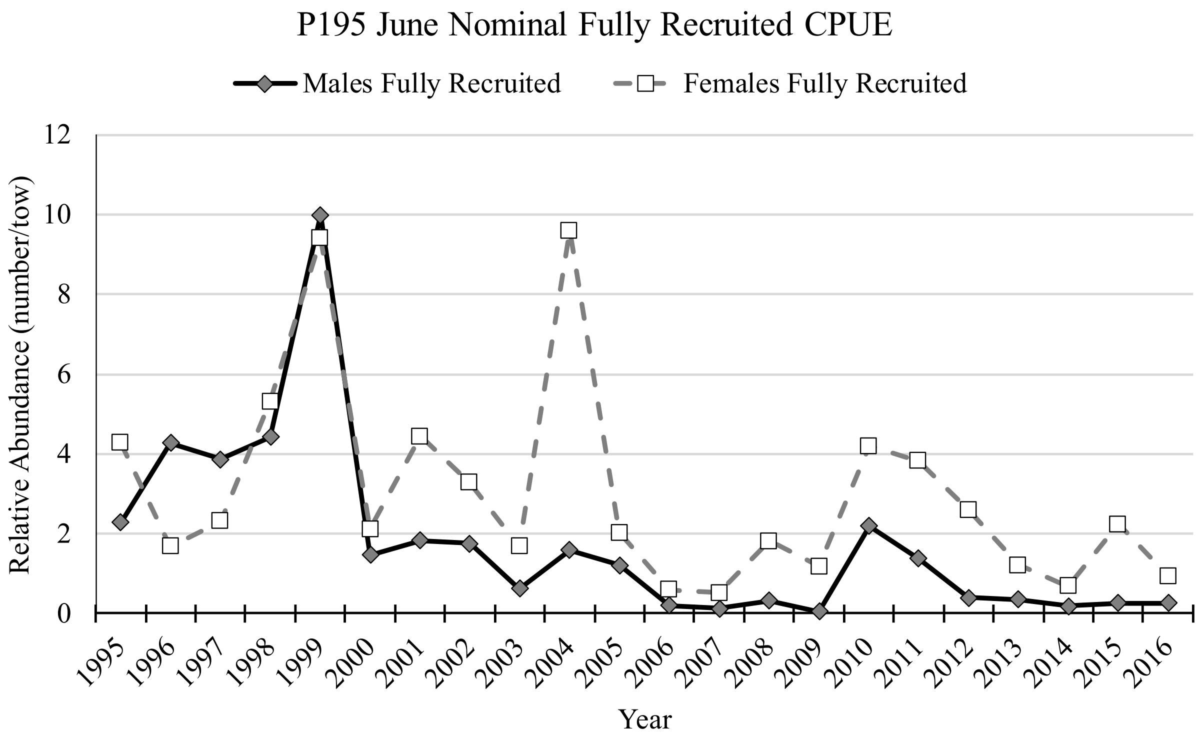


Figure 2.17. Weighted nominal catch-per-unit effort (CPUE; number of crabs per sample) of recruit crabs (<127 mm CW) captured in Program 195 by month and sex, 1995 – 2016 for all strata combined.



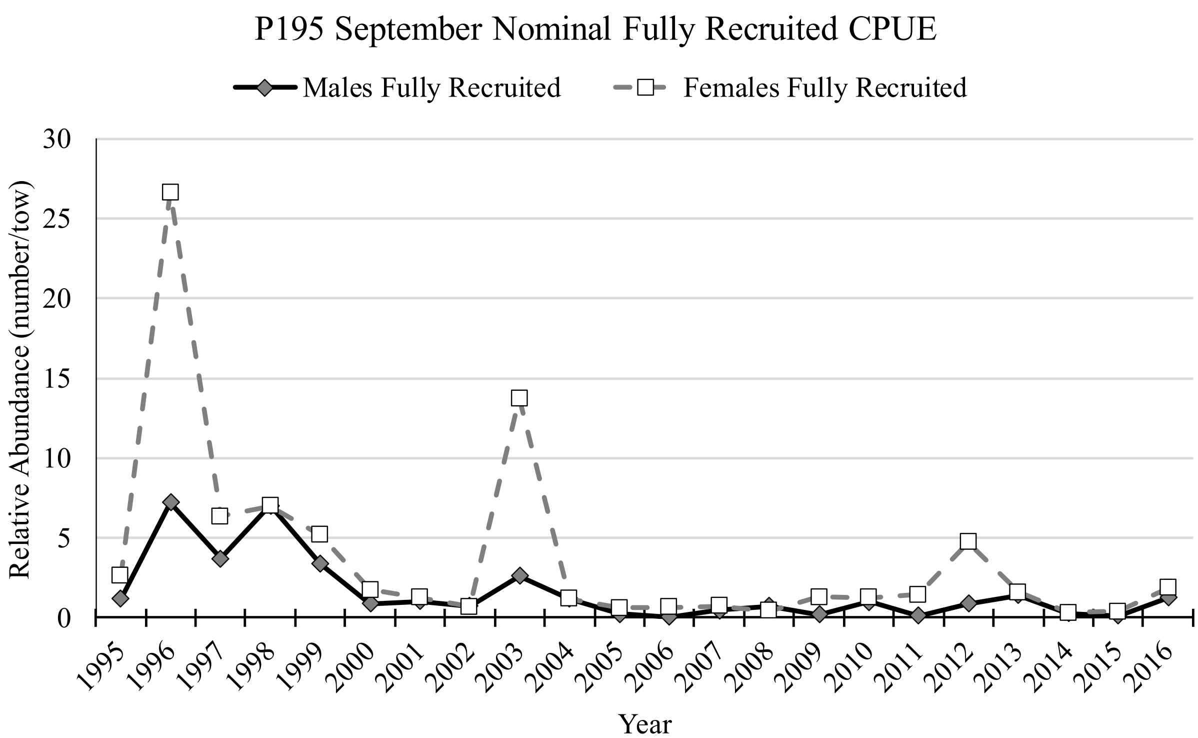


Figure 2.18. Weighted nominal catch-per-unit effort (CPUE; number of crabs per sample) of fully recruited crabs (≥127 mm CW) captured in Program 195 by month and sex, 1995 – 2016 for all strata combined.

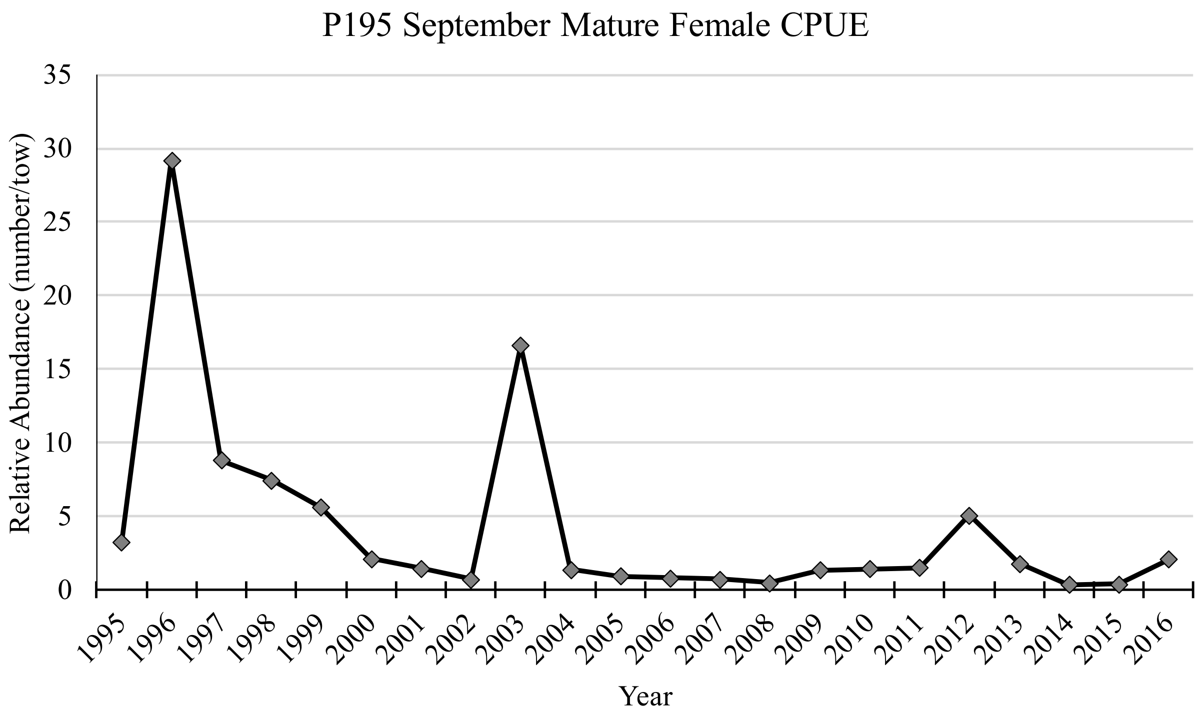


Figure 2.19. Weighted nominal catch-per-unit effort (CPUE; number of crabs per sample) of mature female crabs captured in September in Program 195, 1995 – 2016 for all strata combined.

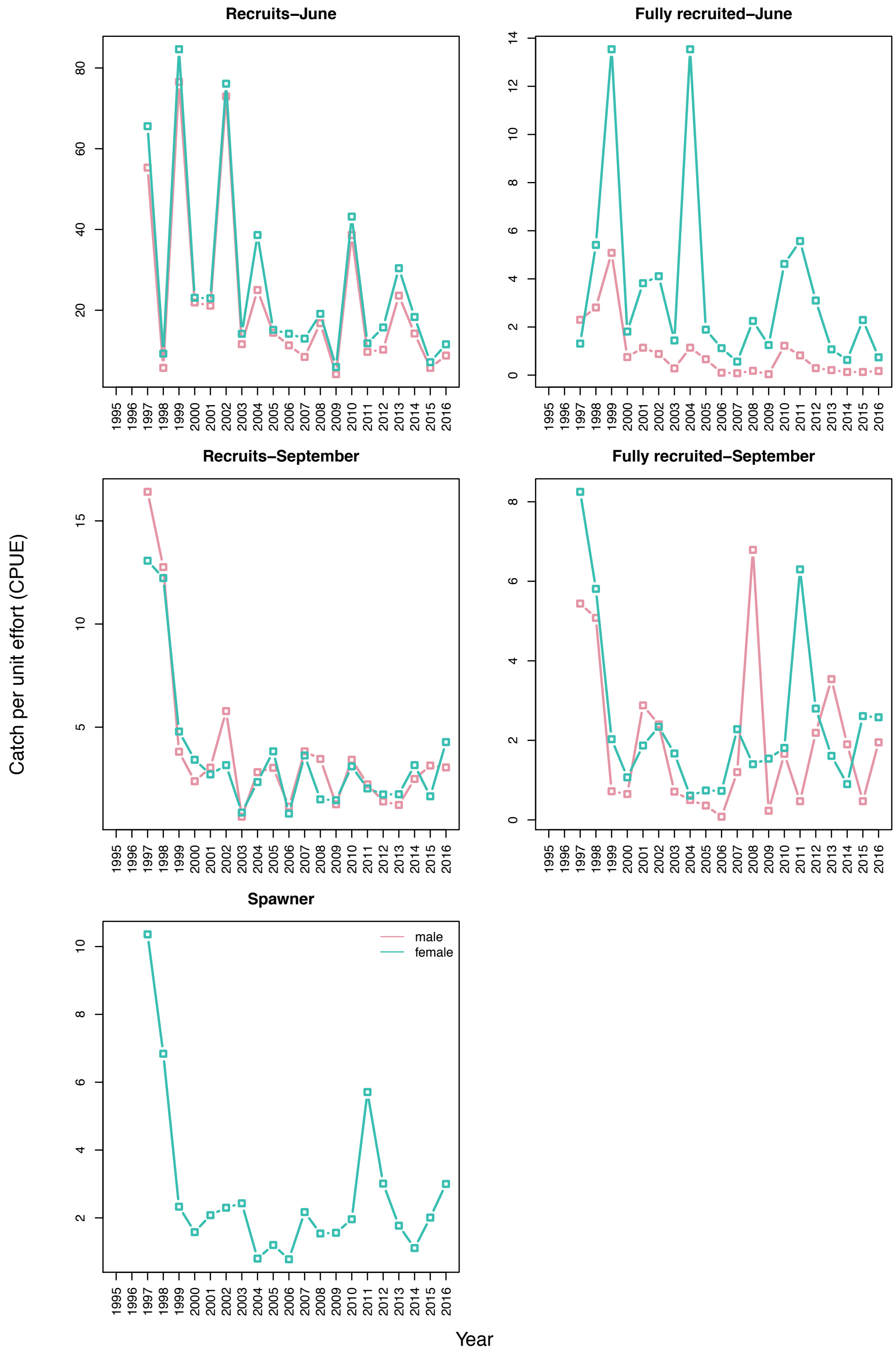


Figure 2.20. Standardized catch-per-unit effort (CPUE; number of crabs per sample) of recruit crabs (<127 mm CW), fully recruited crabs (≥127 mm CW) and mature female crabs (September) captured in Program 195 by month and sex, 1995 – 2016 for all strata combined.

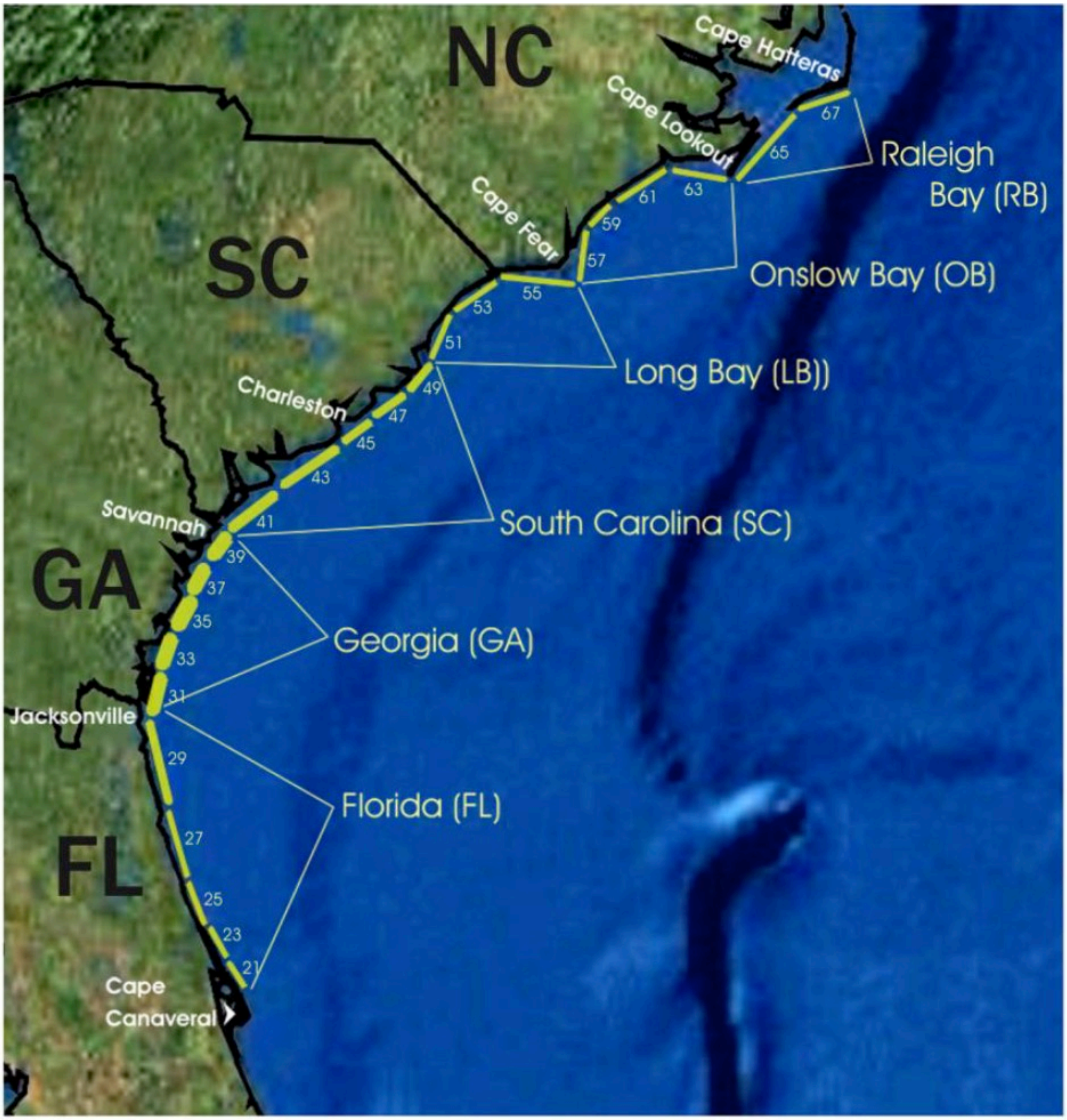
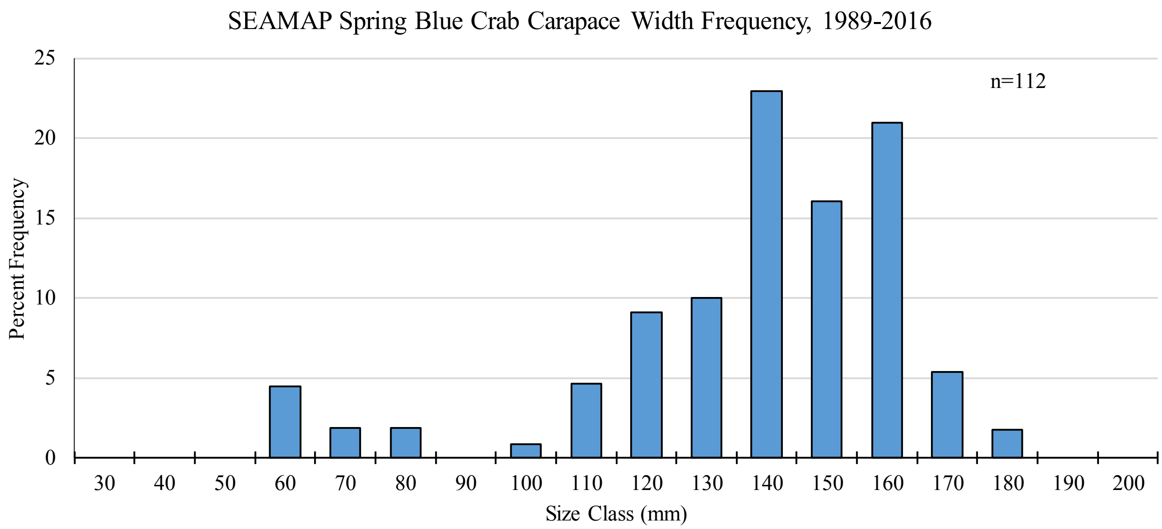
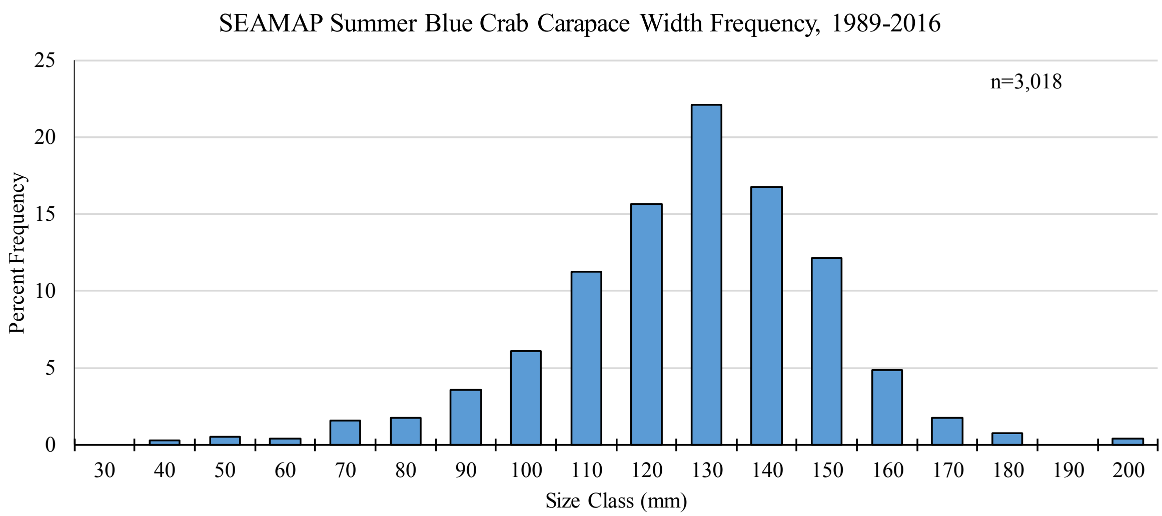


Figure 2.21. Sampling area of the SEAMAP Coastal Survey.





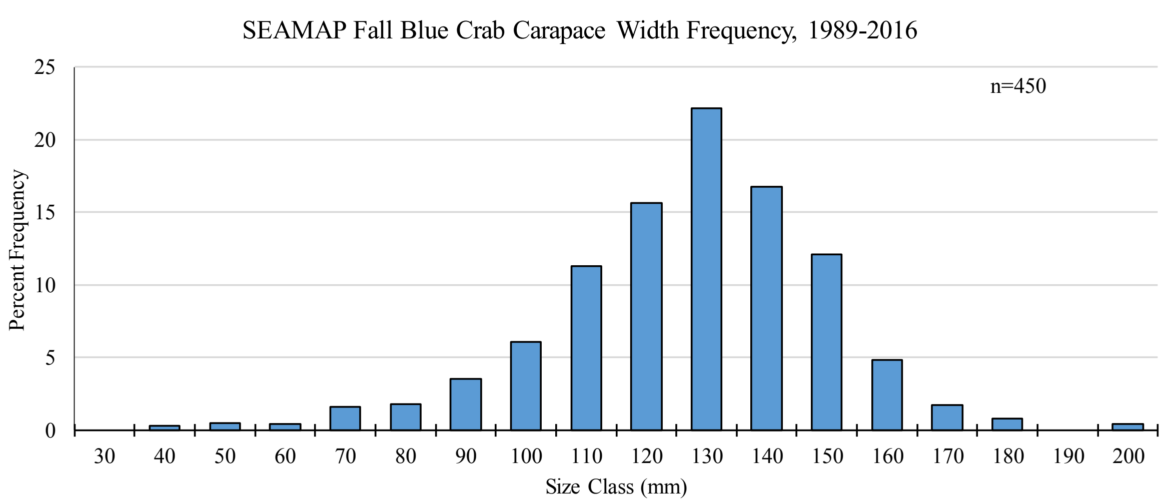
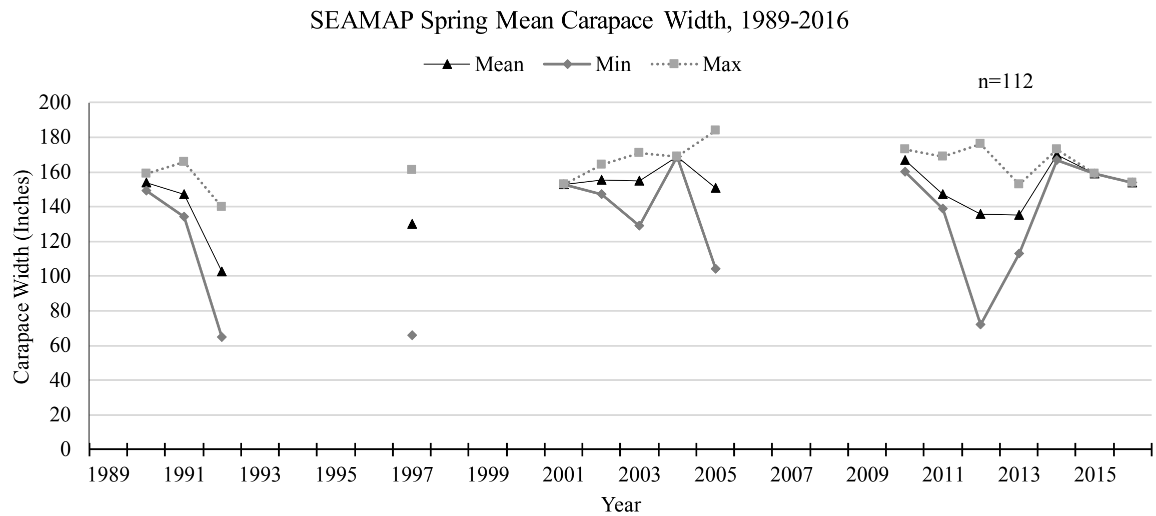
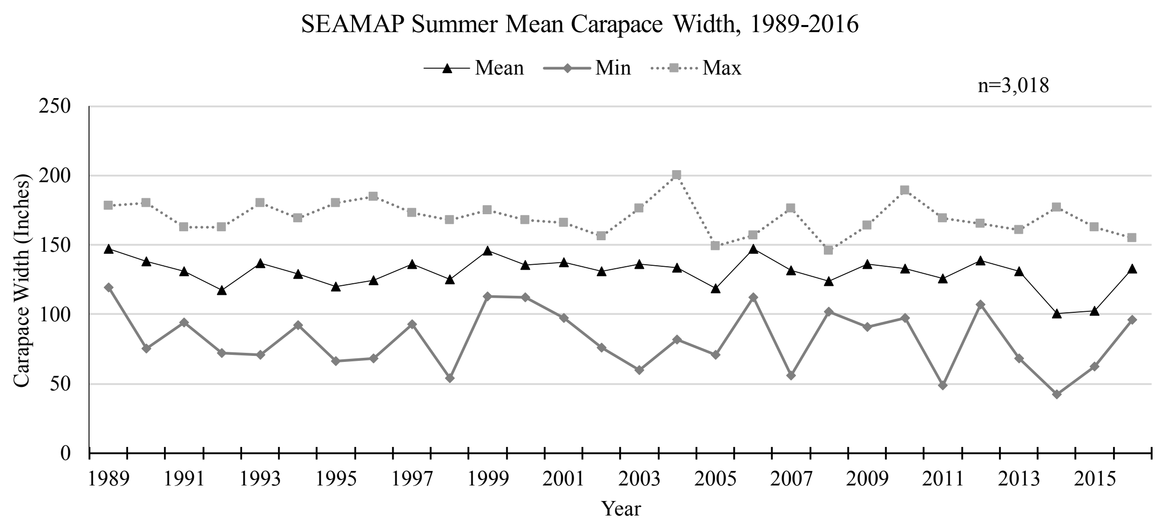


Figure 2.22. Carapace width frequency by season from the SEAMAP Coastal Survey in North Carolina waters, 1989-2016.





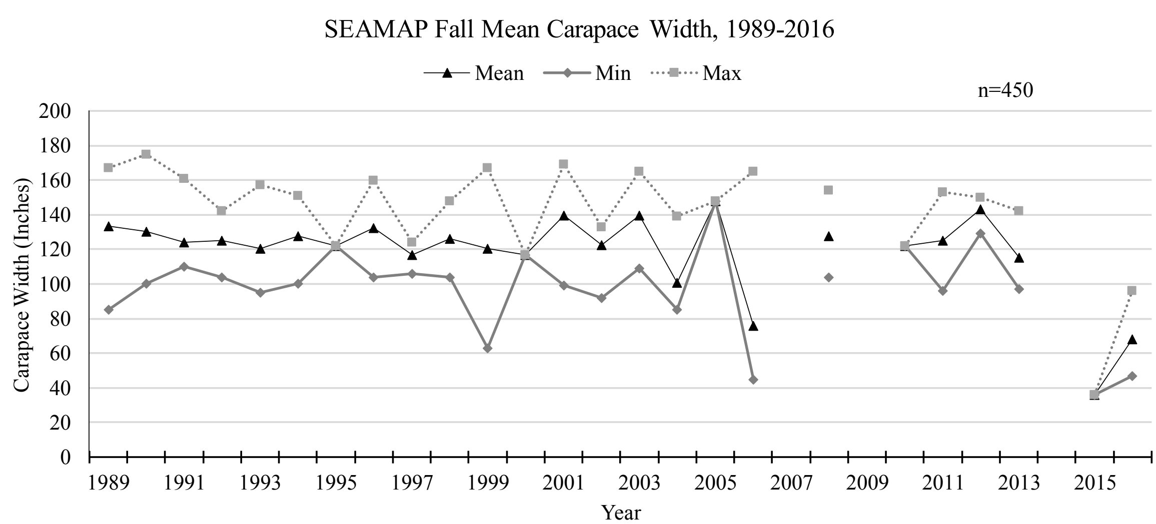


Figure 2.23. Median, minimum, and maximum carapace width by season from the SEAMAP Coastal Survey in North Carolina waters, 1989-2016.

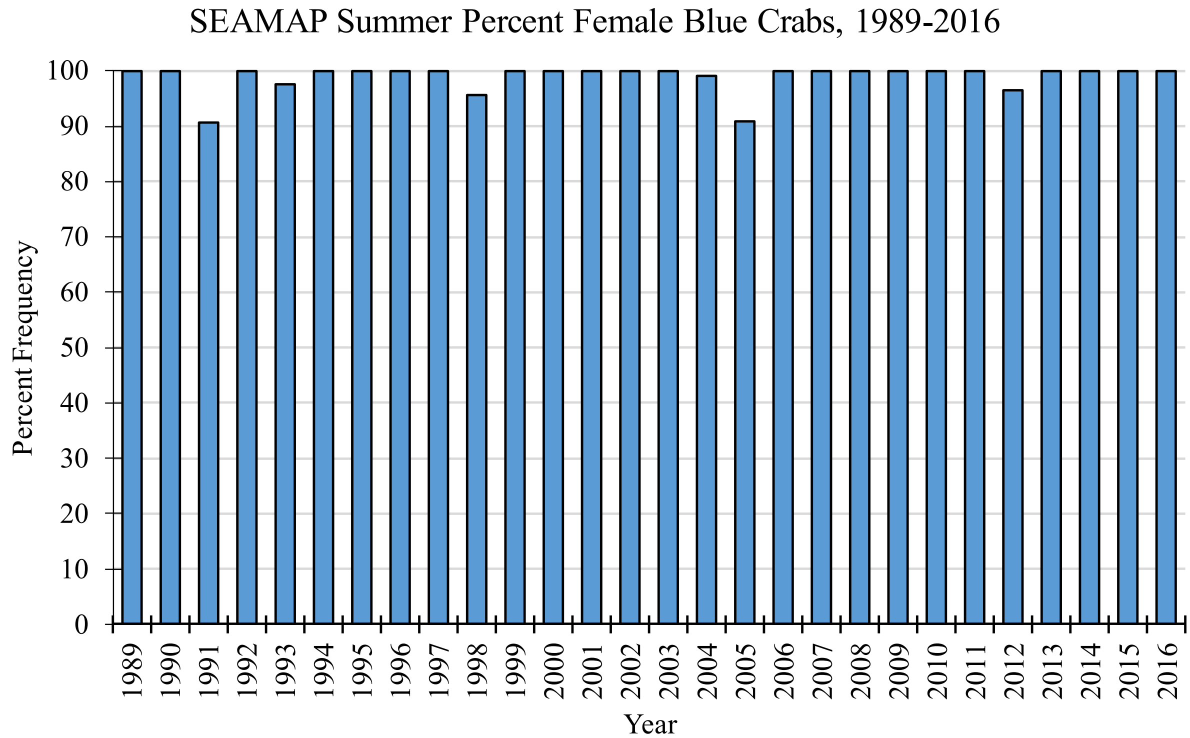


Figure 2.24. Percent of mature female blue crabs in the catch from the summer cruise of the SEAMAP Coastal Survey in North Carolina waters, 1989-2016.

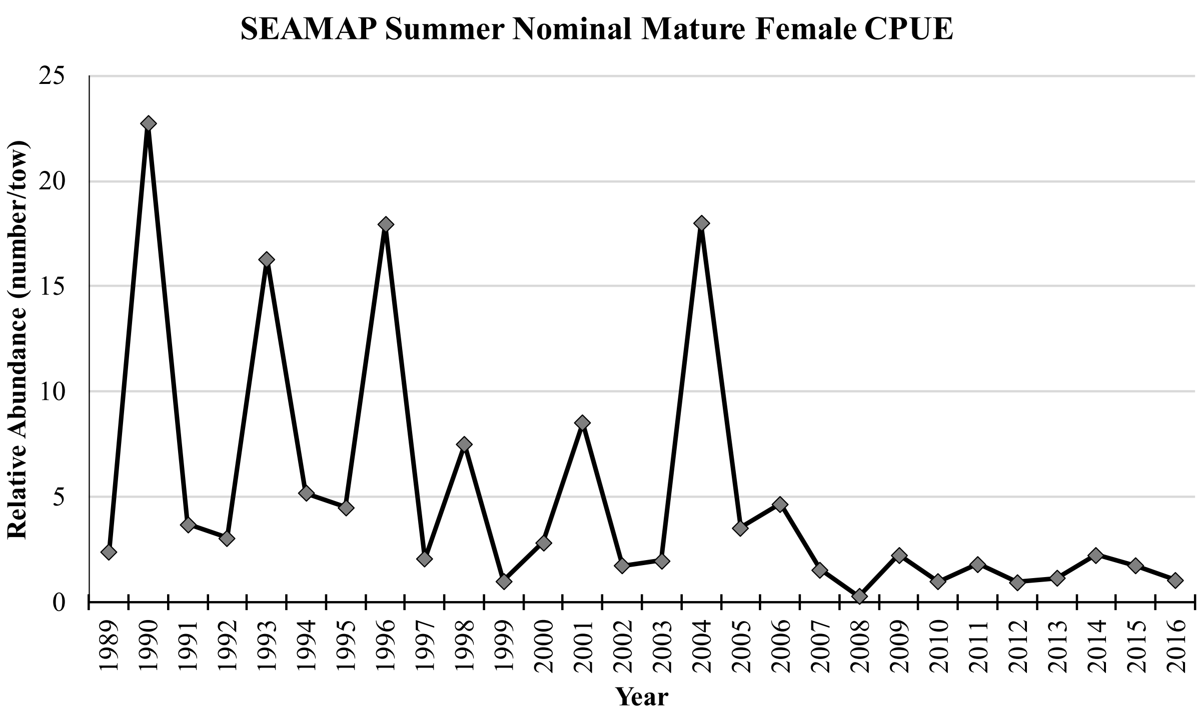


Figure 2.25. Nominal summer CPUE from the SEAMAP Coastal Survey in North Carolina waters, 1989-2016.

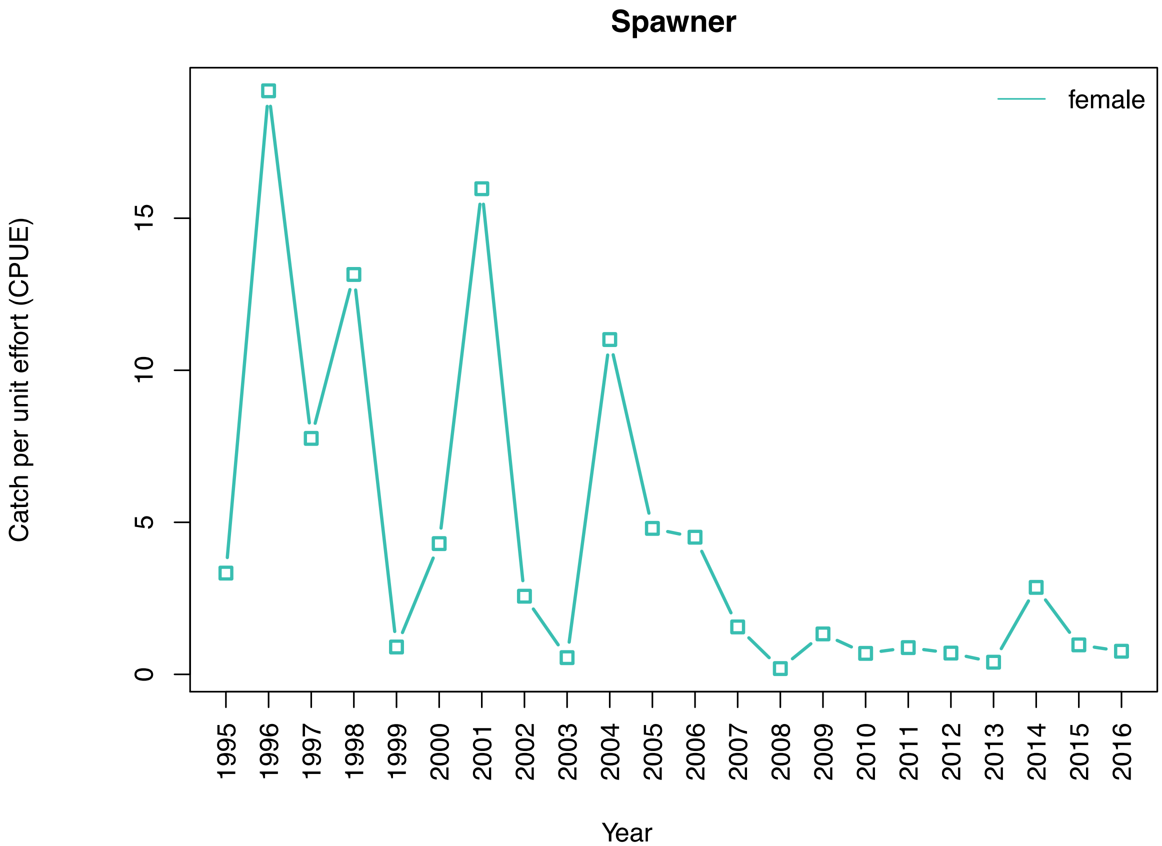


Figure 2.26. Standardized Summer CPUE from the SEAMAP Coastal Survey in North Carolina waters, 1995-2016.

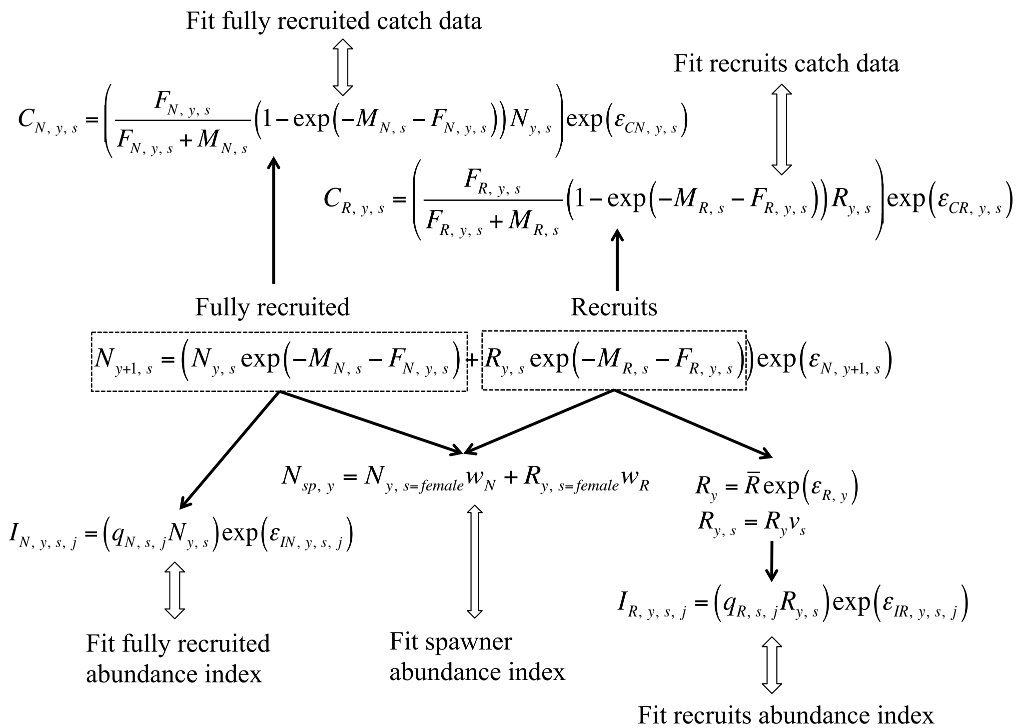


Figure 3.1. Schematic diagram of the two-stage model for North Carolina blue crab stock assessment. Refer to text for symbol explanation.

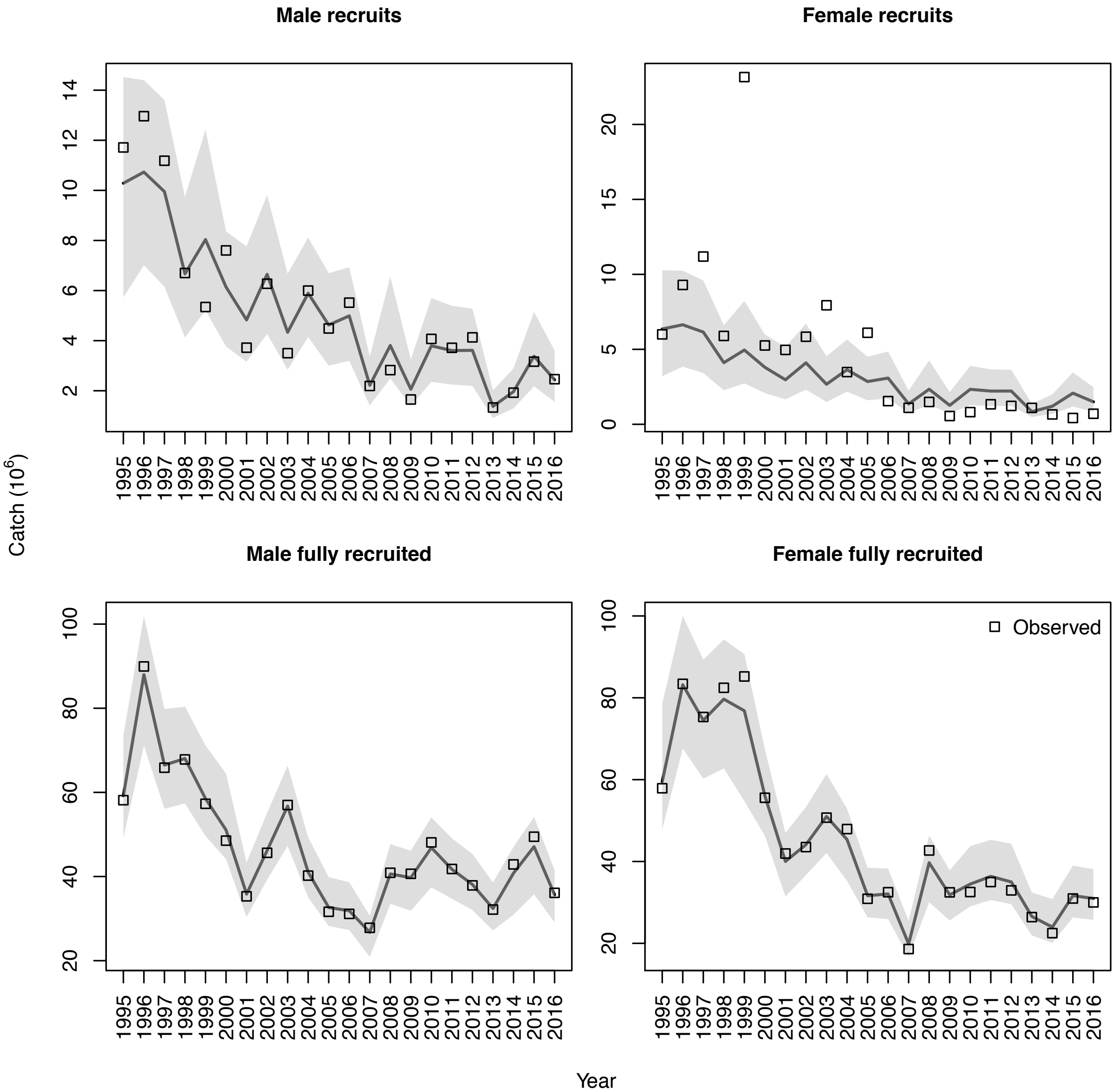


Figure 3.2. Estimated commercial catch of North Carolina blue crab from the baseline model (Model 1), with lines representing posterior mean and shaded area representing 95% credible interval.

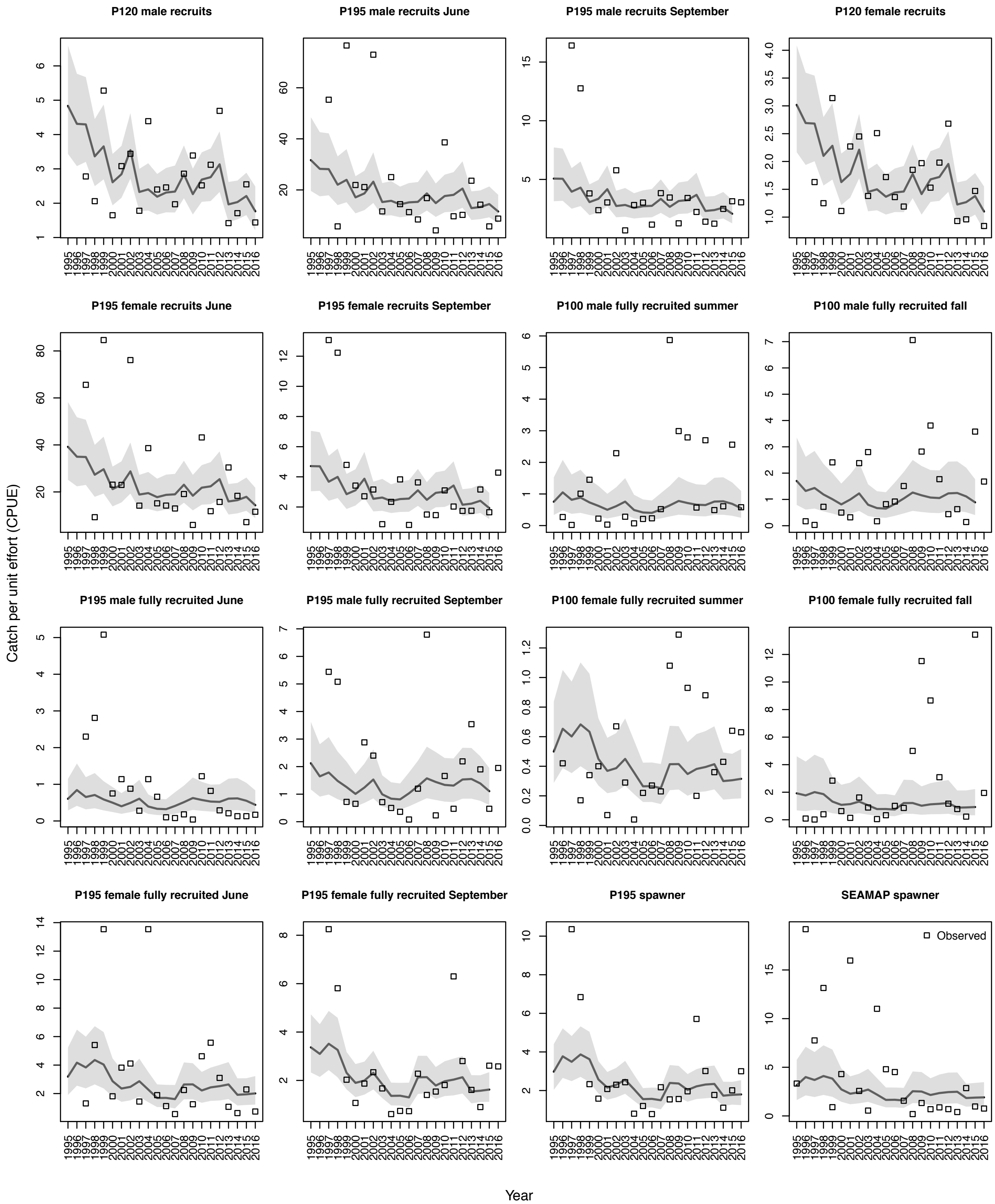


Figure 3.3. Estimated abundance indices of North Carolina blue crab from the baseline model (Model 1), with lines representing posterior mean and shaded area representing 95% credible interval.

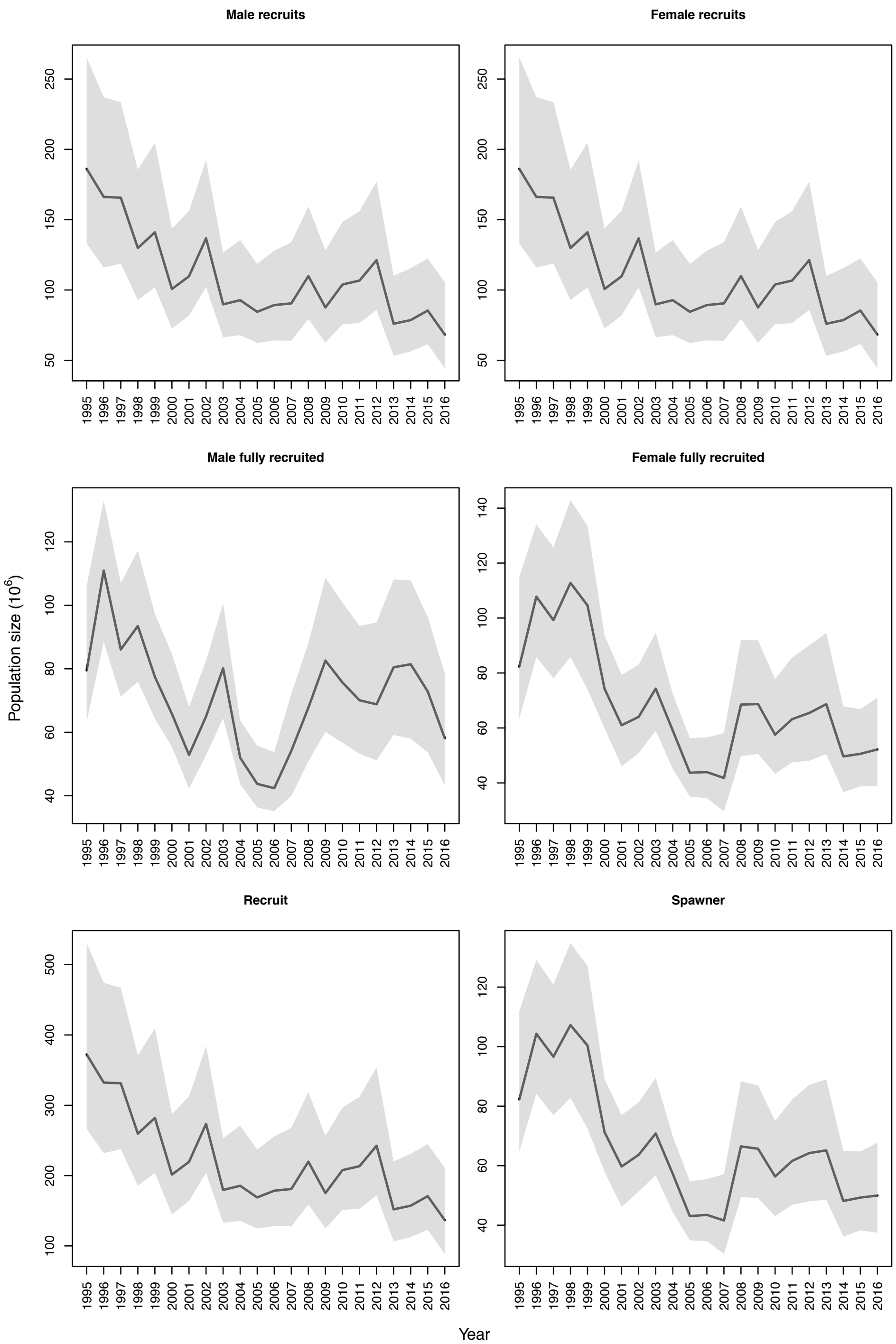


Figure 3.4. Estimated population size of North Carolina blue crab from the baseline model (Model 1), with lines representing posterior mean and shaded area representing 95% credible interval.

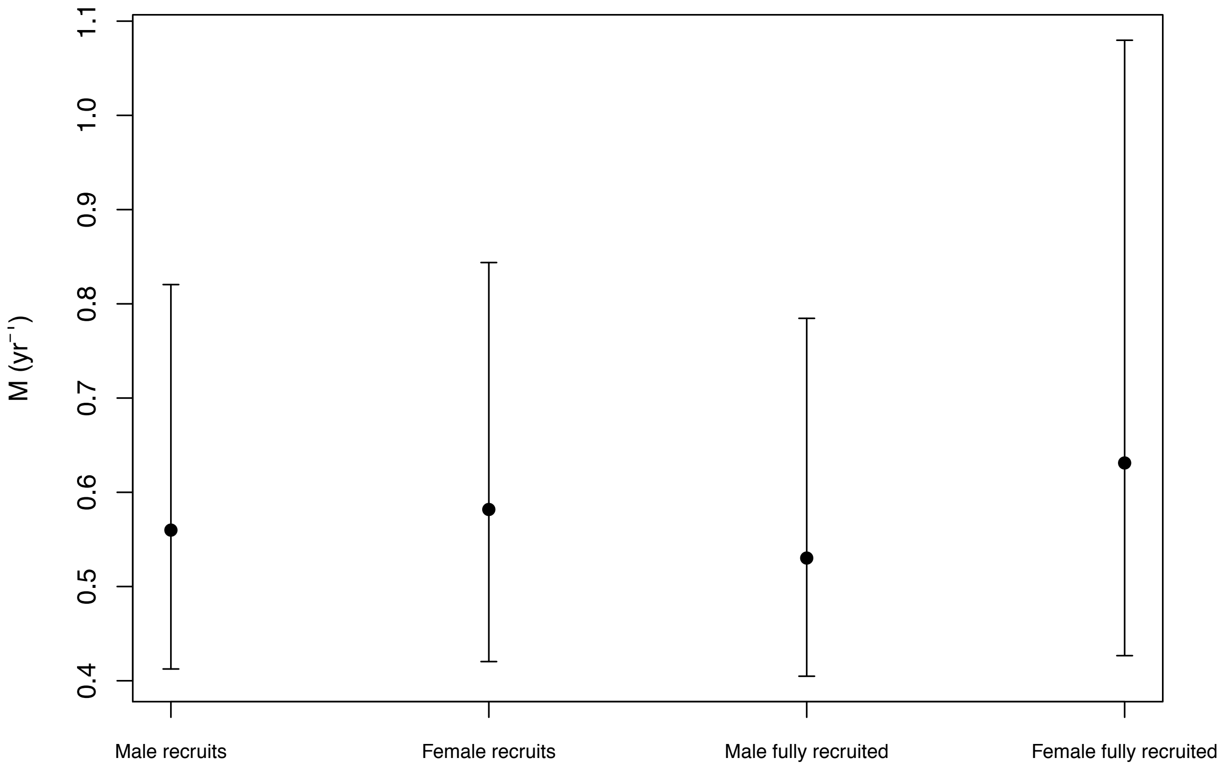


Figure 3.5. Estimated natural mortality (*M*) from the baseline model (Model 1), with dots representing posterior mean and wiskers representing 95% credible interval.

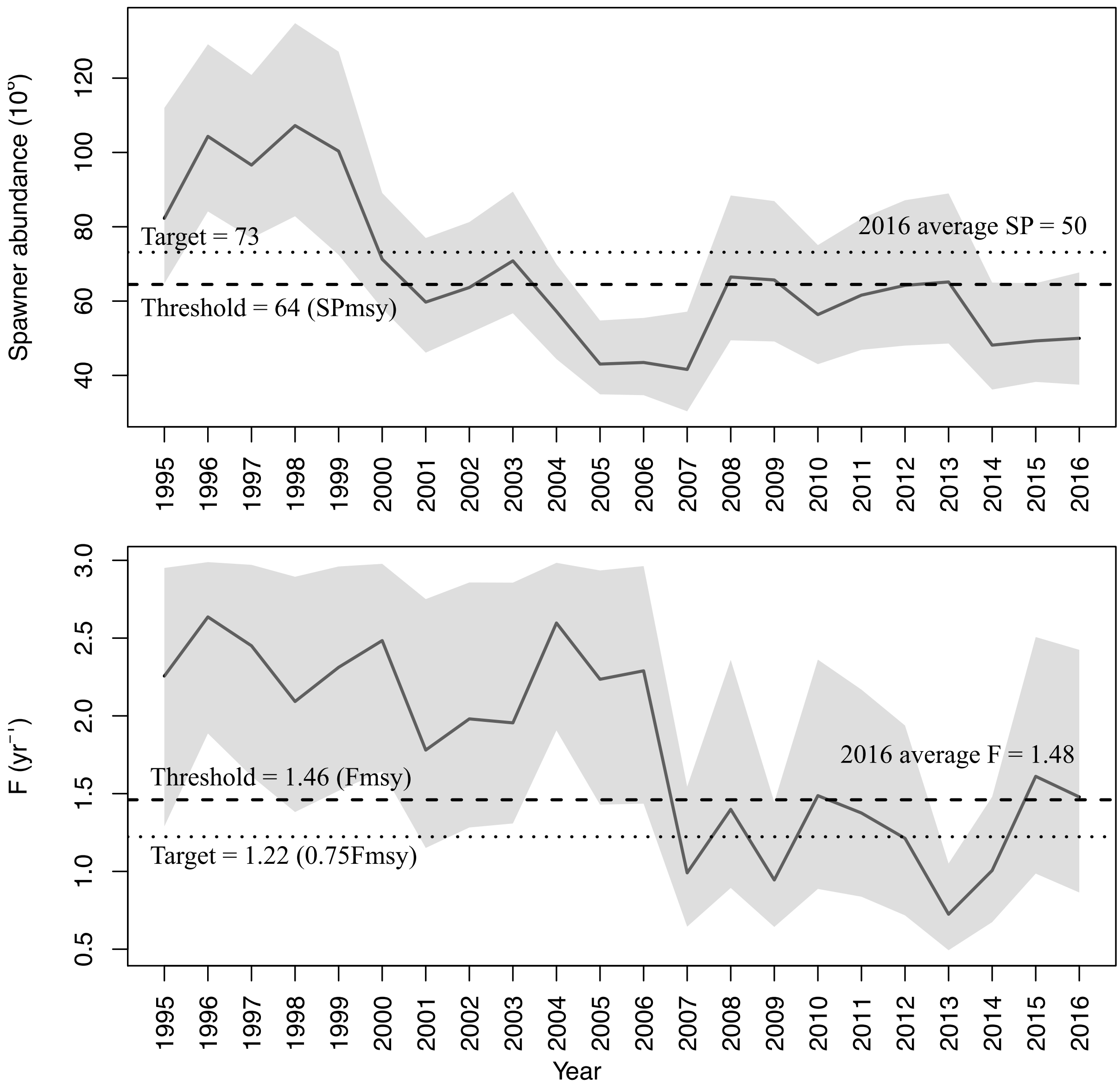


Figure 3.6. Estimated spawner abundance and fishing mortality (*F*) of North Carolina blue crab from the baseline model (Model 1), with lines representing posterior mean and shaded area representing 95% credible interval from the baseline model, Model 1. The threshold and target values are the posterior means.

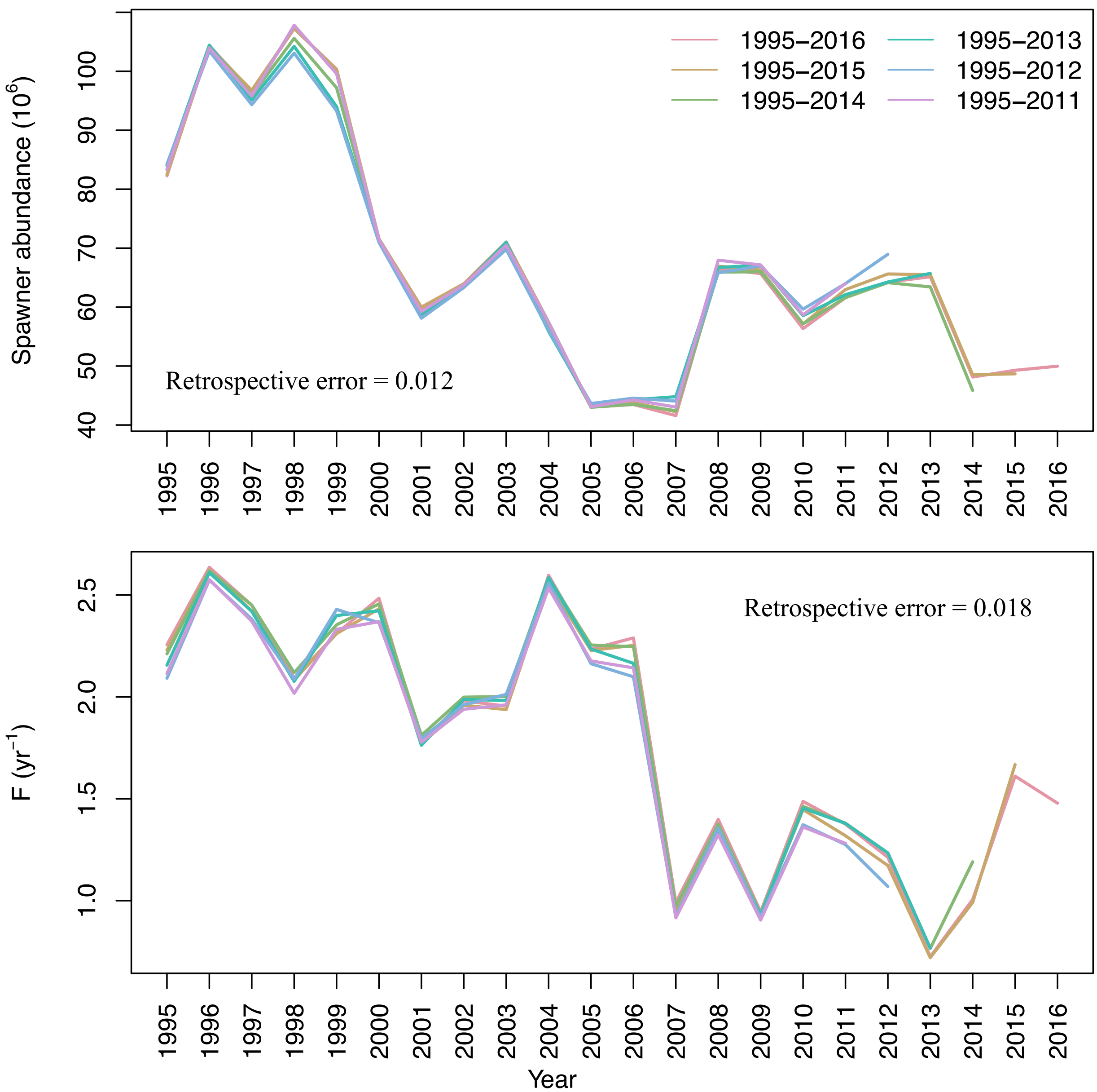


Figure 3.7. Estimated spawner abundance and fishing mortality (*F*) of North Carolina blue crab from a retrospective analysis with additional one year of data added at a time for five years in the baseline model, Model 1. Lines represent posterior mean.

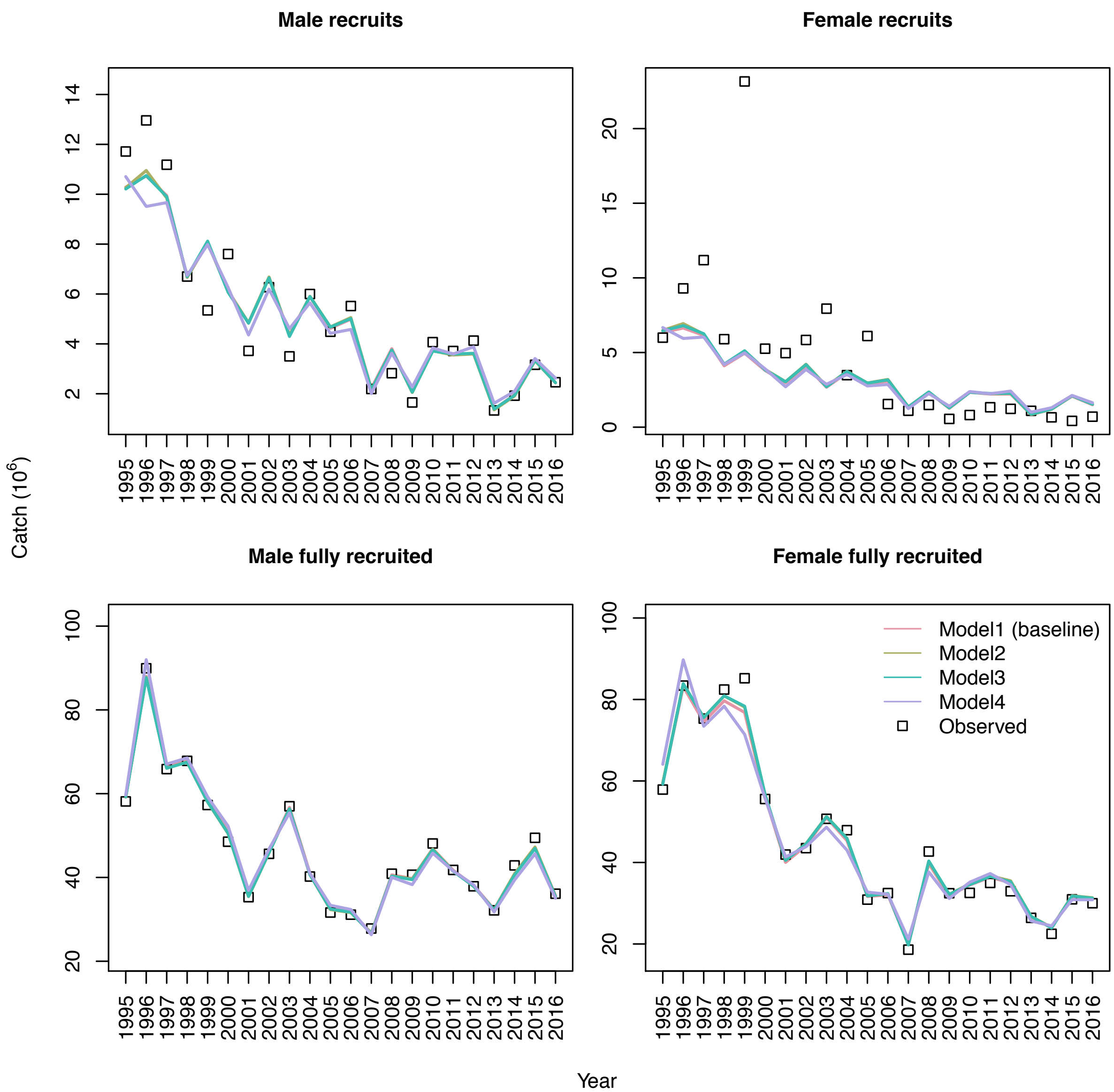


Figure 3.8. Estimated commercial catch of North Carolina blue crab from candidate models, with lines representing posterior mean. The Please refer to Table 3.3 for the explanation of candidate models.

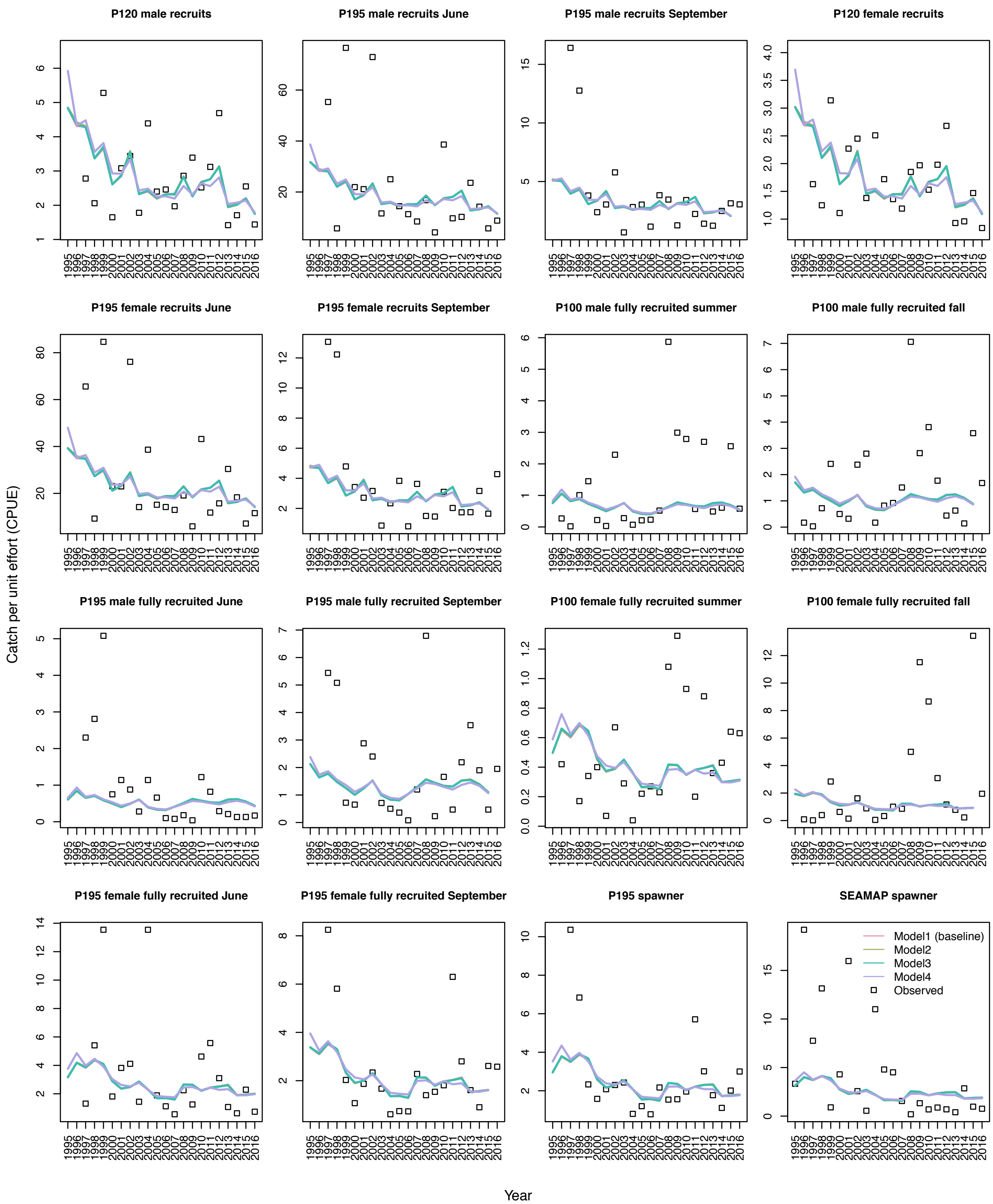


Figure 3.9. Estimated abundance indices of North Carolina blue crab from candidate models, with lines representing posterior mean. Please refer to Table 3.3 for the explanation of candidate models.

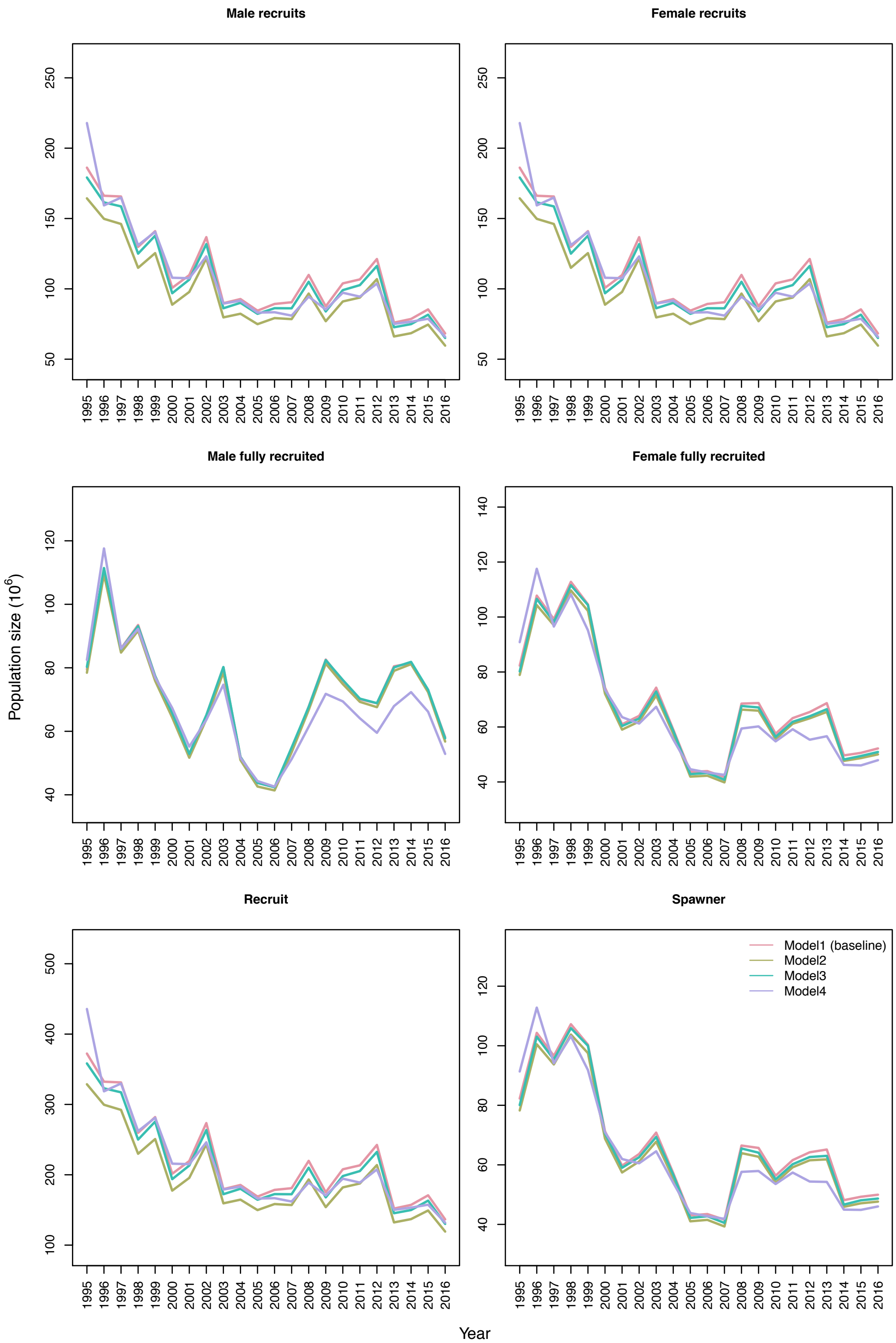


Figure 3.10. Estimated population size of North Carolina blue crab from candidate models, with lines representing posterior mean. Please refer to Table 3.3 for the explanation of candidate models.

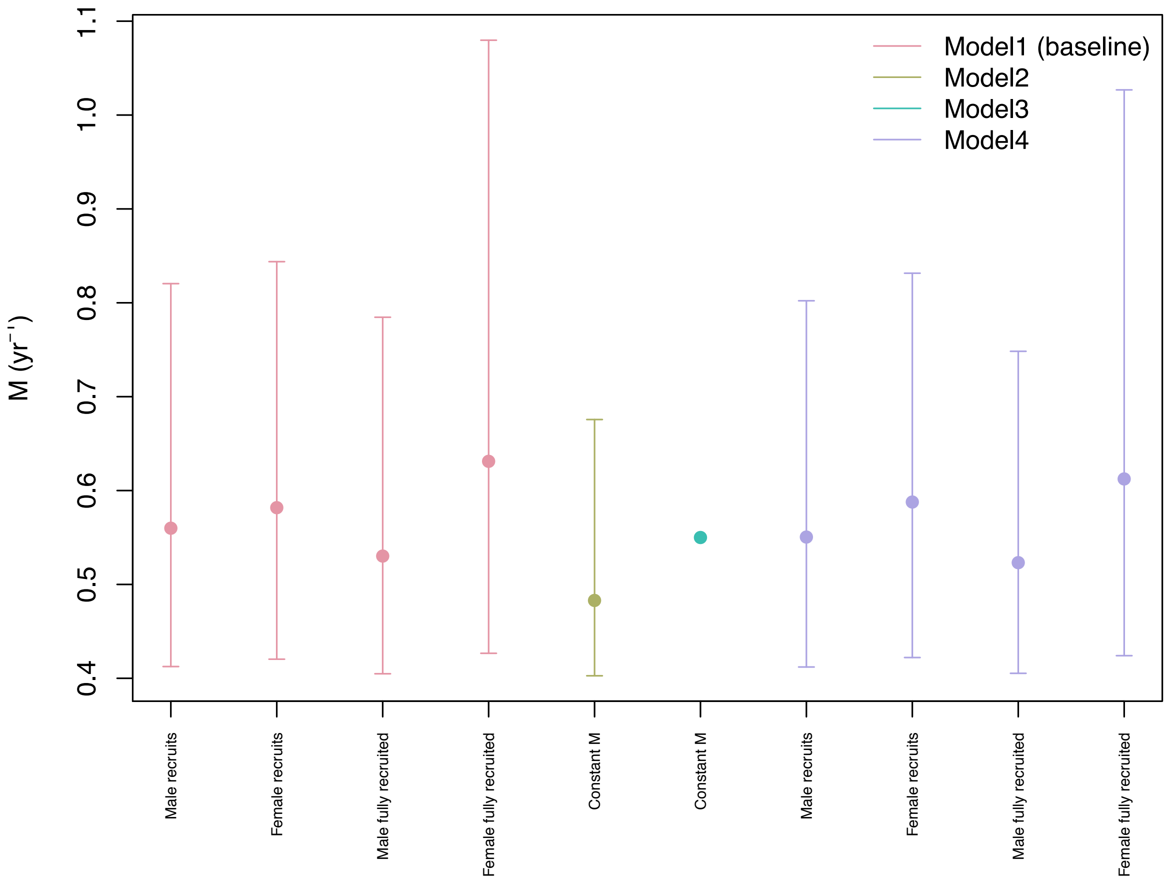


Figure 3.11. Estimated natural mortality (*M*) from candidate models, with dots representing posterior mean and wiskers representing 95% credible interval. Please refer to Table 3.3 for the explanation of candidate models.

Figure 3.12. Estimated fishing mortality (*F*) of North Carolina blue crab from candidate models, with lines representing posterior mean. Please refer to Table 3.3 for the explanation of candidate models.

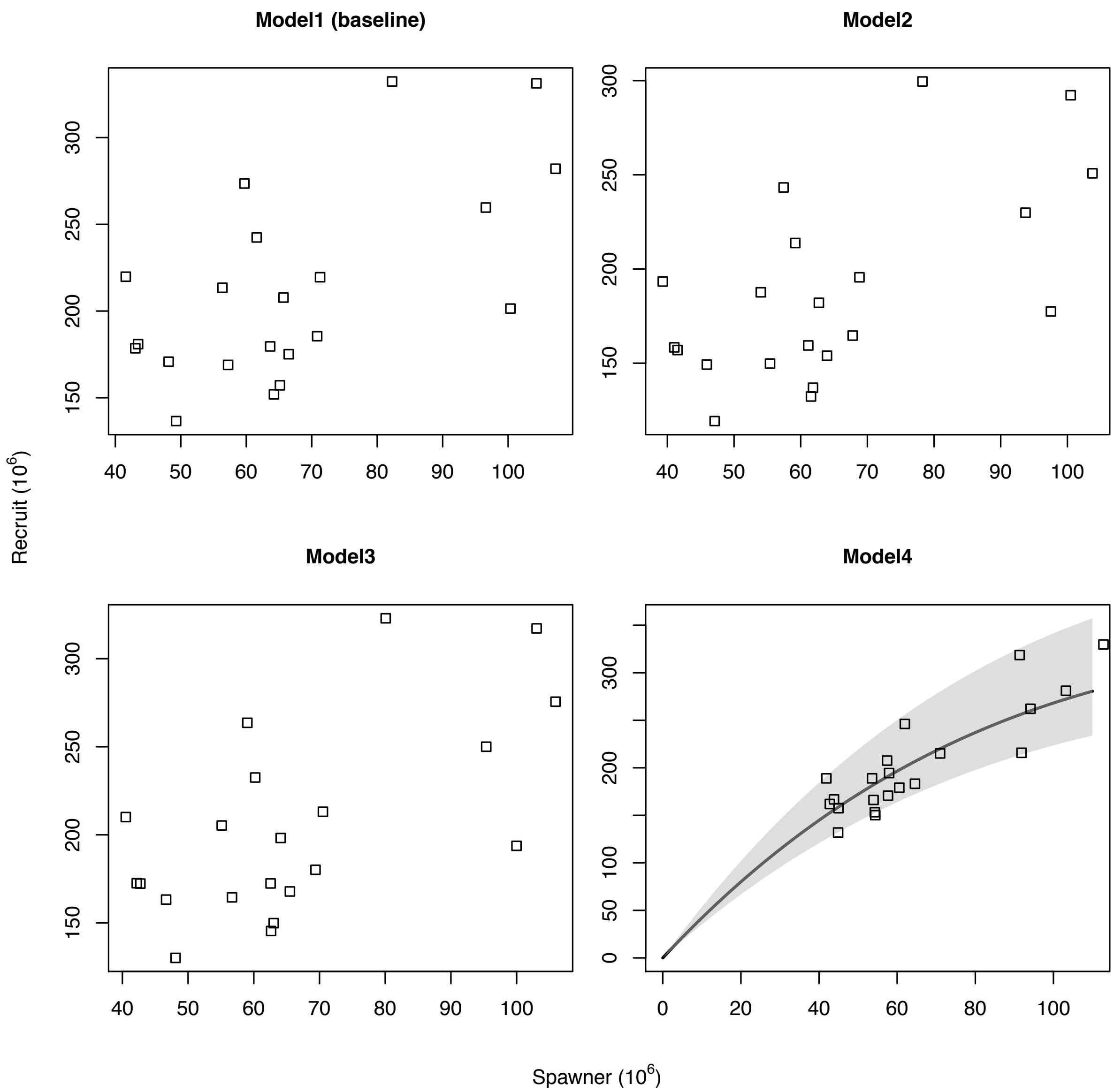


Figure 3.13. Estimated recruitment and spawner relationships from candidate models. Models 1-3 show the estimated annual average of recruits and spawner stock size; Model 4 shows the estimated recruits given a spawner stock size assuming a Ricker curve, with lines representing posterior mean and shaded area representing 95% credible interval. Please refer to Table 3.3 for the explanation of candidate models.

10 APPENDIX

10.1 APPENDIX A: Traffic Light Approach

The blue crab Traffic Light is divided into three separate characteristics: 1) adult abundance, 2) recruit abundance, and 3) production. Each characteristic uses data from several division biological surveys and sampling programs to determine the relative abundance of adult and recruit blue crabs in the population and various production indictors for the stock each year. Under the plan, management measures will be implemented in the blue crab fishery if certain biological triggers are met. To trigger management action, either the adult abundance or production characteristic of the Traffic Light must be at or above the 50% red threshold for three consecutive years to trigger moderate management action and must be at or above the 75% red threshold for two of three consecutive years to trigger elevated management action as established in the plan (Table A1). The recruit abundance indicator, while not used to trigger initial management action, may be used to supplement any management action taken if an adult abundance or production trigger is activated. The three-year period was chosen to prevent taking management action due to annual variability in the blue crab stock and instead base any management response on the observation of a short, but continued declining trend in the population.

As a result of the update with data through 2015, a revision to the Blue Crab Fishery Management Plan was adopted in May 2016 to improve the condition of the blue crab stock. Since management measures were implemented in June 2016, it is too early to tell what effect, if any, they have had on the condition of the blue crab stock.

The most recent update, including data through 2016, indicates the adult abundance characteristic continues to exceed the moderate threshold of 50% red (adult=66% red; Figure A1). This serves as the fourth consecutive year at or above the 50% red threshold for the adult abundance characteristic. The recruit abundance characteristic has exceeded the 75% red threshold for fourth consecutive year (2016=88% red). The production characteristic has met the 50% red threshold (2016=50% red) for the first of three years required before management action must be taken due to the condition of this characteristic.

Table A1. Moderate and elevated management measures under the adaptive management framework for the Blue Crab Traffic Light in Amendment 2 to the Blue Crab Fishery Management Plan.

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 sub-legal 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 sub-legal 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	R4. Prohibit harvest of sponge crabs (all) and/or require sponge crab excluders in pots in specific areas
	R2. Restrict trip level harvest of sponge crabs (tolerance, quantity, sponge color)	R5. Expand existing and/or designate new crab spawning sanctuaries
	R3. Close the crab spawning sanctuaries from September 1 to February 28 and may impose further restrictions	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)	P4. Prohibit harvest of sponge crabs (all) and/or require sponge crab excluders in pots for specific areas
	P2. Minimum and/or maximum size limit for mature female crabs	P5. Reduce peeler harvest (no white line peelers and/or peeler size limit)
	P3. Close the crab spawning sanctuaries from September 1 to February 28 and may impose further restrictions	P6. Expand existing and/or designate new crab spawning sanctuaries
		P7. Closure of the fishery (season and/or gear)

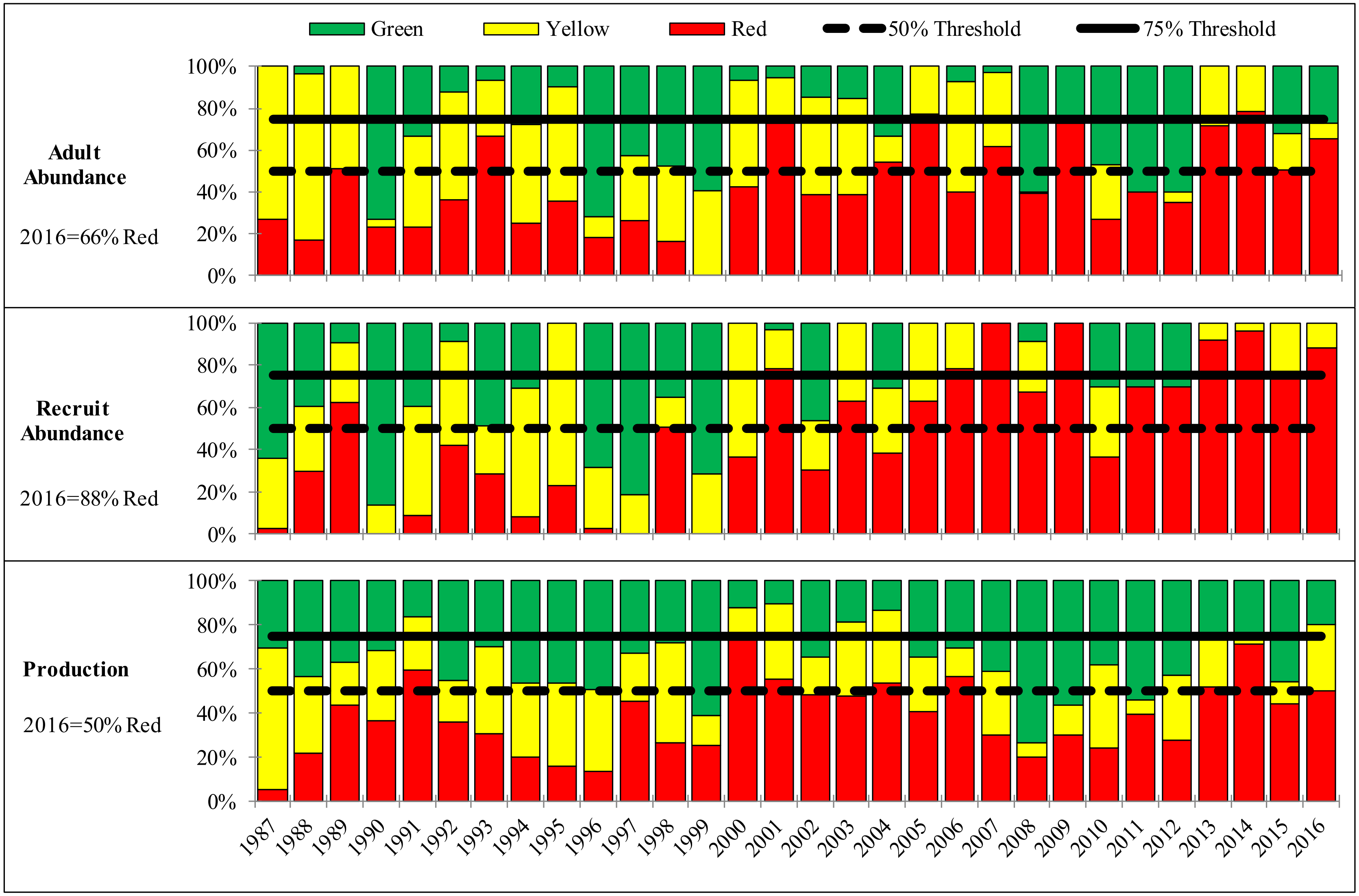


Figure A1. Adult abundance, recruit abundance, and production characteristics for the 2016 Blue Crab Traffic Light update.

10.2 APPENDIX B: External Peer Review Report

External Peer Review Report
for the
2018 Stock Assessment
of
Blue Crab in the North Carolina

Jeffrey Brust (chair), New Jersey Division of Fish and Wildlife

Dr. Edward Hale, Delaware Department of Natural Resources and Environmental Control

Dr. Robert Leaf, University of Southern Mississippi

Genine McClair, Maryland Department of Natural Resources

April 16, 2018

EXECUTIVE SUMMARY

A peer review of the North Carolina blue crab (*Callinectes sapidus*) stock assessment was conducted in New Bern, North Carolina on March 27-29, 2018. The Peer Review Panel (RP) evaluated the data sources and model relative to a set of Terms of Reference provided by the Stock Assessment Team. Based on the information provided in the assessment report and during the peer review workshop, the RP accepts the stage- and sex-structured Catch Survey Analysis model as appropriate for management use.

The fishery dependent and independent data sources, including potential biases in each one, were well described. The data sources used in the model were determined to be appropriate, but the RP suggests additional analyses to further evaluate potential data sources and better justify their inclusion or exclusion. The index standardization process was also well documented, and is consistent with best practices. The panel would have liked to see a list of all covariates available for each index, rather than just those selected. We also recommend further investigation into development of regional indices, and exploration of environmental events or indices to help explain trends in abundance.

The RP is in agreement that the CSA model used in this assessment is a significant improvement over the qualitative traffic light approach used previously. The stage-based structure is appropriate given the life history of blue crabs. We express some concerns about possible overparameterization, inconsistencies between survey and fishing time steps, and model assumptions about life history characteristics (M, growth). Sensitivity runs indicate the model is robust to these uncertainties, but recommendations are provided to address the RP's concerns.

Reference points selected are based on historical performance of spawner per recruit to prevent a "worst case scenario" (*i.e.* falling below a previously observed low point). The RP recognizes the difficulty establishing more quantitative reference points given the available data, but expresses concern over the utility of the reference points selected. It was noted that there was little variability in SPR over time, and the degree of risk in the SPR values selected is unknown (*i.e.* they could be ultra-conservative or ultra-liberal). The RP provides guidance into development of other reference points, such as those used for blue crabs in other areas, or species with similar life histories.

Stock status was determined as overfished and overfishing. This is consistent with the Assessment Team's professional opinion and observations about stock dynamics in recent years, and sensitivity runs indicate that this determination is robust to model assumptions. The RP concurs with this determination, but again encourages investigation into other reference points, which may affect status determination.

The Assessment Team provided a list of research recommendations that address data gaps and other uncertainties. The RP concluded that the list is relevant, but provides guidance on prioritization of the different items.

Overall, the RP is impressed with the amount of research and analysis conducted by the Assessment Team. Prior to and during the review workshop the Assessment Team was very responsive to the RP's questions and request. Further, an external peer review for a state level stock assessment is recognized as being above and beyond the capacity of most states. Staff of the NC Division of Marine Fisheries are commended for their efforts.

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1 INTRODUCTION

The North Carolina Division of Marine Fisheries (NC DMF) held an external peer review workshop on March 27-29, 2018 in New Bern, NC to evaluate the 2018 North Carolina blue crab (*Callinectes sapidus*) stock assessment. Members of the review panel (RP) included fishery biologists and natural resource managers from other state agencies and academia. This assessment of the North Carolina blue crab stock is the second to undergo an in-person peer review workshop; previous assessments had been reviewed through a desk audit process. Overall, the RP is impressed with the State's commitment to treating local assessments with the same level of scrutiny as regional, national and international assessments. In this respect, North Carolina sets a high bar for other states to follow in order to promote science-based management of its marine resources.

The assessment team (AT) provided a draft of the stock assessment report to the RP approximately three weeks prior to the review workshop. At the time, the AT requested that potential sensitivity run suggestions be provided prior to the review workshop since the model took approximately 4-6 hours to run, limiting the number of sensitivity runs that could be performed during the workshop. The RP submitted several ideas, as well as identified some topics that needed additional clarification or discussion during the review workshop.

Prior to the workshop, the AT also provided a set of Terms of Reference (ToR) for the RP to address in order to focus the review and deliberations on relevant aspects of the assessment, including data sources, model choice and parameterization, reference points, stock status, and research recommendations. The RP concludes that the AT addressed each of the ToR adequately, and that the model and model results are suitable for management use. Additional comments on each of the ToR are provided through the remainder of this report.

2 TERMS OF REFERENCE

2.1 Evaluate the thoroughness of data evaluation and presentation including:

Overall, the RP found that the AT adequately addressed this ToR. The individual biological monitoring programs, both fishery dependent and fishery independent, were well documented. Further, the AT acknowledged survey specific limitations and potential biases after a description of each survey, and the application of GLMs to standardize indices was well described. However, the RP did identify several potential strategies that may have helped clarify the data sources used, justify inclusion of data sources, and explain the process for index and model selection. These are described in detail below.

2.1.1 Justification for inclusion or elimination of available data sources

The AT provided thorough descriptions of the multiple monitoring programs considered, including fishery-dependent (Commercial Monitoring-Trip Ticket Program[TTP], Biological Characterization [P436]; Recreational Monitoring-Telephone and Mail-in surveys) and fishery independent surveys (Estuarine Trawl Survey[P120]; Juvenile Anadromous Survey[P100]; Pamlico Sound Survey[P195]; Southeast Area Monitoring and Assessment Program[SEAMAP]). The AT acknowledged survey specific limitations and potential biases after a description of each survey. For example, the AT acknowledged that the TTP fails to capture information on unsuccessful trips, recording only positive catch events. However, the RP notes that the survey response rate was not characterized by region of the recreational monitoring survey despite stratifying the survey design. Also, the AT limited survey participation to recreationally licensed individuals. The P120 survey was reported to potentially inflate the abundance of mature female crabs in Pamlico Sound by including transient females in abundance estimation. Further, the survey has the potential to report fewer crabs than are actually present because of a failure to sample waters deeper than 2 m. Similarly, P100 was described as potentially biased due to a failure to sample a broader depth range, as well as potentially limited in spatial scope which could significantly misrepresent the presence of mature female crabs. Conversely, P195 was described as potentially biased because of an inability to sample shallower waters and navigate complex habitat structure which may act as refugia. SEAMAP was accepted for use by the AT, and it is the only survey that samples the entire stock distribution, but it was largely recognized by the RP to potentially misrepresent trends in statewide or smaller regional patterns in abundance given the offshore sampling design.

The AT described the monitoring programs excellently; however, the RP did identify a few issues that may help clarify the available data sources, index standardization and model parametrization. First, a conceptual presentation of life history dynamics used to inform model input would have been helpful to the RP in order to document significant biological milestones encapsulated within the model parameters. For example, further detail on molt frequency and timing with respect to the model assumption that all crabs would enter the fully recruited stage after one year would help to evaluate the merits of this assumption. Similar discussion on the links between the model and natural mortality (*e.g.* pre- and post-recruitment rates), predation, and environmental tolerances (*e.g.* effects of storm events on recruitment, mortality, and availability to survey gear) would prove useful to justify model structure and parameterization.

The description of the standardization process included in the explanation of the P120 survey was excellent. However, the RP recommends the AT document all available individual covariates (not just those selected) and error structure listed for each standardized survey within the report. This information was provided upon request at the peer review by the AT. Overall, the RP felt that a series of more comprehensive tables and figures, including those developed/presented at the peer review documenting a comprehensive list of the indices considered, model type and error structure of selected standardized indices, a quantitative comparison of surveys (e.g. correlation matrix), as well as corresponding figures (e.g. GLM fit and residual plots) would have helped the RP consider more fully the surveys chosen and methods used to standardize indices prior to the review. Further, both trace plots and marginal density plots would have been helpful in order to consider diagnostics of model convergence and parameter estimation. Similarly, Gelman diagnostics would have been helpful to the RP in assessing differences among chains (Gelman and Rubin, 1992), and plots of the posterior distributions would have helped the RP assess model differences. Finally, the RP would have appreciated the presentation of a continuity run of the traffic light approach within the assessment to compare the preferred model with an updated result from a previously approved management strategy.

The RP found the overall presentation of monitoring programs well documented in the stock assessment. However, several recommendations should be considered to improve the next benchmark stock assessment. In particular, the RP recommends providing additional information and justification on the data sources evaluated, and additional types of data sources should be considered. The RP feels that, although the data sources used in the assessment were appropriate, the assessment report itself lacked sufficient justification for inclusion of specific data sources beyond listing the available monitoring programs. The potential exclusion of data sources from the assessment (e.g. recreational survey, commercial CPUE, total number of commercial licenses sold) should have been made available within the body of the stock assessment report to comparatively assess all available data streams. The RP also recommends that additional evaluation of the data sources with respect to each other should be performed. For example, available surveys, particularly fishery-dependent monitoring programs, should have been examined to determine if significant correlations were present with commercial landings. Correlation matrices of the difference indices (with appropriate time lags) are instrumental in looking for consistent signals. These were provided at the RP's request during the assessment workshop, but should be included in the draft assessment report. Finally, environmental information, including fresh water input, river flow, frequency and intensity of environmental perturbations (*i.e.* hurricanes), as well as large scale climatic indices (*e.g.* AMO/NAO/ENSO) should be explored to determine if any mechanistic physical parameters affecting recruitment or abundance could be identified and potentially included within the assessment model. However, the AT did present a number of comparisons including commercial landings relative to large hurricane events to the RP at the peer review for further consideration.

2.1.2 Consideration of survey and data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size)

The RP found the description of data bias following each monitoring program helpful in assessing potential weaknesses of individual surveys. However, several recommendations should be considered to improve the next benchmark stock assessment. In particular, the RP recommends that a discussion on comprehensive issues with current sampling methodologies, including the lack of larger-scale, regional information, and whether or not surveys were tracking population abundance. Also, a proportion of positive tows for individual monitoring programs would be helpful in assessing the utility of individual sampling programs within the assessment model. Finally, appropriate comparisons of the different data sources with each other are very useful for evaluating the information content of the different sources. Much of this information was supplied to the RP upon request during the peer review workshop, but should be included in the assessment report.

2.1.3 Calculation and standardization of indices and other statistics

The RP found the calculation and standardization of indices and other statistics consistent with current best scientific practices. Specifically, the RP appreciated the incorporation of environmental variables into index standardizations given the historical information regarding environmental consideration within the assessment report. The application of GLMs to standardize indices was well documented in P120. However, a table of covariates and error structures for individual standardized indices is recommended for all indices in future assessments within the assessment report. Also, environmental indices, including those described in Section 2.1.1 of this report should be considered to examine potential relationships affecting recruitment and/or abundance. Finally, other diagnostics of index and model performance would have helped the RP better understand model parameter selection and comparative performance among models (e.g. GLM fit and residual plots, trace plots and marginal density plots, Gelman diagnostics and posterior distributions).

2.2 Evaluate the adequacy, appropriateness, and application of data used in the assessment.

Multiple data sets from throughout the stock range in North Carolina were used as inputs into the Catch Survey Analysis model broken out by stage (recruit < 127mm and fully recruited > 127mm) and sex, including commercial landings and several fishery-independent indices. The commercial landings data were appropriately characterized using biological samples from Program 436, which ran for most of the assessment time-frame. The development and use of standardized indices for the fishery-independent surveys as input for the model was a significant improvement from previous assessments, as a means to address the influence of environmental variability. The GLM approach used was appropriate and well documented, however a list of all available covariates for each index, as well as presentation of additional diagnostics of standardization (e.g. deviance explained, AIC, etc.) would improve the RP's understanding of the effects of standardization.

A limitation for the indices utilized (with the exception of SEAMAP) is that they each cover a small spatial and temporal component of the unit stock. As such, while some of the indices showed similar patterns for the same stage and sex, others did not. There also appeared to be very real differences in regional trends between Pamlico and Albemarle sounds. Since assessment models typically have difficulty reconciling conflicting indices, the RP discussed the merit of developing combined indices by sex and stage outside the model rather than treating each survey as an independent index. Upon request by the RP, the AT ran a sensitivity analysis that incorporated combined indices to provide a more comprehensive stock-wide signal by stage and sex for model input. This model run had minimal impacts on biomass trends, and no effect on stock status. However, the RP recommends further exploration of a means to fully capture stock-wide changes in abundance for future assessments. Combining indices may also benefit the model implementation by reducing the number of parameters that must be fit.

A temporal change in abundance is reflected in some of the datasets after 2007, and it was unclear what caused this drastic change and whether it was explored by the AT. Therefore, the RP requested a sensitivity run that explored a time-block to allow for differences in catchability after 2007. While, this run had better fits to some of the indices, it increased the number of estimated parameters and did not change stock status. This sensitivity run supports the use of a single time-block, but further exploration into the data sets to investigate this temporal change will provide further justification for inclusion/exclusion of these data sets for future assessments.

To evaluate the contribution of each index to the model the RP suggested sensitivity runs that serially removed indices. As time did not allow for this process, the AT ran a sensitivity run that dropped Program 100, the Albemarle Sound juvenile trawl survey, which had the most pronounced change in abundance after 2007, and a run that dropped Program 120, the Estuarine Trawl Survey, which samples south of Albemarle Sound. Both of these sensitivity runs had negligible effects on the results compared to the base model, suggesting the model is robust to these data inputs.

The RP also discussed the appropriateness of SEAMAP as an index of abundance for the model considering the habitat sampled by the survey and unknown coastal mixing of nearby stocks (e.g. Chesapeake Bay). While SEAMAP is the only survey that samples the entire stock range within NC, the RP is concerned that there is limited connectivity between the component of the stock sampled in the ocean and the remainder of the stock in the estuaries.

The start date for the assessment was 1995. While harvest of blue crabs from North Carolina has been occurring for much longer than the assessed timeframe, the start date was adequately justified by reliable commercial landings following the implementation of the TripTicket Program in 1994 and survey data with associated environmental data becoming available in 1997. However, the RP recommends future reports consider the effect of historic harvest levels on starting biomass and evaluation of stock status.

A large data gap for this assessment is unknown recreational harvest. Expert opinion from the AT is that recreational harvest is minimal compared to commercial harvest, and available data are not considered reliable enough to estimate harvest accurately, so recreational harvest was assumed to be zero. However, it is known that recreational harvest is not zero, and data from other states suggest that it may be substantial. A sensitivity run conducted during the review workshop indicated the model results and stock status are robust to this uncertainty. Further, the RP acknowledges the difficulty in estimating recreational harvest based on the available mail surveys and no license requirement to recreationally crab in the state. Regardless, we highly recommend inclusion of recreational harvest in future assessments.

The annual time-step of this model assumes recruits grow to be fully recruited within one year. Some discussion of the accuracy of this growth assumption for all crabs < 127 mm is needed. The RP recommends exploration of a narrower recruit criteria (e.g. 80mm – 127mm) applied to survey data sets. As discussed in Section 2.1.1, a detailed review of the species life history and its implications for the model set up and parameterization would be useful.

2.3 Evaluate the adequacy, appropriateness, and application of method(s) used to assess the stock.

The assessment integrated three sources of information (life history, fishery-dependent and fishery-independent) into a Catch-Survey Analysis (CSA), specifically catch-multisurvey analysis, that was implemented using a Bayesian parameter estimation method. The use of CSA was initially applied to four groundfish stocks in New England - Georges Bank and Southern New England yellowtail flounder and Georges Bank and NAFO SA 4X haddock stocks (Collie and Sissenwine, 1983). The approach is a stage-based population dynamics model that divides the population into pre- and post-recruits. The population model, involves fitting the time series of observed abundances of pre-recruit and post-recruit individuals to obtain estimates of stage-specific population estimates and fishing mortality rates. The approach has been reviewed and the method is robust to variation in input parameters; however, absolute estimates are sensitive to the ratio of catchabilities for each stage (Mesnil, 2003). CSA has been applied to a variety of crustacean species including northern shrimp in the northwest Atlantic, king crab in Alaska, and blue crab in Delaware Bay, Chesapeake Bay, and the eastern and western Gulf of Mexico (Miller et al., 2011, 2005; VanderKooy, 2013; Wong, 2010; Zheng et al., 2002). Miller et al. (2005, 2011) refined the model to include multiple surveys and relaxed the assumption that catch is known without error.

The RP concluded that the Catch-Multiple Survey Analysis presented in the Stock Assessment of the North Carolina Blue Crab 1995-2016 is appropriate to understand this stock's fishery and biological dynamics. The stage-based modeling approach is necessary given the difficulty of age determination of crustaceans. Stage-based methods are often used for management and conservation when the length-at-age relationship is not well understood (Rogers-Bennett and Leaf, 2006). The sensitivity runs in the assessment report, and those requested by the RP, further indicate that the model is robust to the assumptions used in the model. The use of quantitative stock assessment methods is an improvement over those such as the traffic light methods used previously for this stock.

Although the RP believes the model configuration is adequate, we believe that three aspects of the temporal dynamics of the model should be addressed. The RP advises that each of the input time series included in the model should be on the same temporal scale. Particularly, the commercial harvest should coincide temporally with the life-history of the blue crab stock in North Carolina and coincide with the indices of abundance – August 31 to September 1. The RP agrees with the decision to lag the fall fully recruited indices forward to the next year, but with up to 30% of the harvest occurring after the index is developed, this could create inconsistencies between the index and population. Adjusting the fishing year to be consistent with the index year will alleviate this concern.

Another structural issue in the model that we recommend the AT review and discuss is the time span of the assessment. The stock has been exploited by both the recreational and commercial sectors for a very long time, and identification of the relative magnitude of harvest from each sector is necessary.

The third temporal aspect of the model that we would encourage the AT to review is the temporal scale of the indices of abundance used in the assessment model. We encourage the AT to review the indices of abundance to identify the time period (months) and associated length-class (minimum and maximum carapace lengths) that are representative of the pre- and post-recruit individuals. Such an approach would require censoring the indices of abundance using methods as described in Sections 2.1 and 2.2 of this report.

We would encourage the AT to consider reducing the number of parameters that are estimated in the model. One way this could be accomplished is to aggregate sexes which would result in increased parsimony because the number of catchability parameters would be reduced. Similarly, the aggregation of sex in the model and the reasonable assumption of a 1:1 sex ratio may result in a greater precision of fitted abundance indices.

The review panel was concerned that estimates of some biological characteristics are not consistent with those of the natural stock, particularly the estimated natural mortality rates. We believe that the magnitude of the natural mortality rate estimates for both the pre- and post-recruit stages are unreasonably low – at least when compared with those incorporated into the Chesapeake Bay blue crab stock assessment (Miller et al., 2011, 2005). That the natural mortality rate estimates of the pre-recruit and post-recruit stages are equal does not seem biologically reasonable. We believe that aggregating sexes and using an informed prior on the natural mortality rate is necessary and desirable as it would provide more structure to model and perhaps reduce the problematic boundary condition estimates exhibited by the posterior distribution. Further, the RP is concerned about the ability for natural mortality to be estimated within the model, especially when the estimated values are so different from previously published estimates (*e.g.* those in the Chesapeake Bay).

The *de facto* alternative model used in the assessment was a qualitative "traffic light" approach that made use of a variety of indices to describe the fishery and the biological conditions of the stock (Caddy, 1999). We believe that an alternative model, such as a biomass dynamics model, should be used to support the assessment. The use of an alternative model can be used as a validation of the results of the stage-structured model. Surplus production models of blue crab have been used previously for this purpose, notably for the Chesapeake (Miller 2011) and Gulf of Mexico (VanderKooy, 2013). In these assessments the production model can provide support for the reference point MSY.

2.4 Evaluate the adequacy and appropriateness of recommended stock status determination criteria. Evaluate the methods used to estimate values for stock status determination criteria.

The AT established biomass threshold and target reference points as spawner per recruit (SPR) values 30% and 40% greater than the average of three lowest SPR values observed over the time period of the assessment. Fishing mortality reference points were set at the F values that produced these levels of SPR. The AT indicated that a poor fit to the spawner-recruit relationship and difficulty estimating an unfished (virgin) biomass prevented development of more commonly used maximum sustainable yield (MSY) reference points, or those based on overall spawning potential. The RP notes that there is little variability in SPR over time, and the degree of risk in the SPR values selected is unknown (*i.e.* they could be ultra-conservative or ultra-liberal). Also, it would be useful to present the YPR and SPR surfaces, rather than just the time series, in order to evaluate the selected reference point values relative to alternative values.

The RP recognizes the difficulty establishing more quantitative reference points given the available data, and status determinations appear robust to model assumptions using the reference points selected; however, the RP recommends the AT investigate development of more quantitative reference points. For example, stock assessments for blue crab in the Gulf of Mexico (Vanderkooy 2013) and Chespeake Bay (Miller et al 2011) have similar issues fitting the spawner-recruit relationship, yet both establish MSY-based reference points. We believe that although MSY or MSY proxy reference points, though plagued with considerable uncertainty because of the environmental dynamics that impact the stock, should be explored and discussed. At a minimum these could be used as qualitative references for management (Fogarty and Gendron, 2004).

Blue crab population dynamics are considered to be highly influenced by regional environmental variation (Vanderkooy, 2013). Vanderkooy (2013) notes that for the Gulf of Mexico Blue Crab stock: “Changes in the supply and distribution of rainfall could have significant impacts on estuarine productivity and threaten blue crab fishery sustainability”. Recruitment of Atlantic menhaden (*Brevoortia tyrannus*) is also highly influenced by a number of interacting environmental factors and processes (Buccheister et al. 2016), and management is based on relative spawning potential (ASMFC 2017). We recommend further investigation into methods to estimate unfished biomass, and therefore development of reference points based on spawning potential.

Other possible reference point methods include egg per recruit models, as have been used for both US and Canadian lobster (although this method is not currently used for either stock), or incorporation of environmental parameters to improve understanding of recruitment dynamics. Leaf and Friedland (2014) used environmental indices of stock productivity to identify drivers of recruitment patterns of Georges Bank Haddock.

We reiterate that although status determination appears robust to the model, the RP has concerns about the reference points selected. A number of alternatives are provided above, with a priority on MSY-based reference points. The above guidance should not be considered a comprehensive discussion on the available alternatives, and the AT is encouraged to conduct research into appropriate reference points given the life history and data gaps, and also to further evaluate the risks associated with per recruit reference points selected.

2.5 Do the results of the stock assessment provide a valid basis for management for at least the next five years given the available data and current knowledge of the species' stock dynamics and fisheries? Please comment on response.

The RP is satisfied that the sex- and stage-structured CSA model presented as the base run of the assessment report is suitable for management use for the next five years. A number of uncertainties and possible areas of concern with the available data, model assumptions and structure, and reference points have been identified throughout this report that could be addressed to improve the model in the future; however, sensitivity runs clearly indicate that the model results and status determinations are robust to the RP's primary areas of concern. Further, the results of the assessment are consistent with the lead biologists' perceptions of the fishery and stock dynamics. These two points provide credence to the RP's determination that the model provides a valid basis for management of North Carolina's blue crab stock.

Although the RP approves the use of this model for the next five years, we do not advocate that management decisions over that entire time period be based on the results of a 2018 model run. Because of the short life span of blue crabs, as well as other biological and environmental influences, it is strongly recommended that the model be updated at least once within the approved management time period of 5 years.

2.6 Evaluate appropriateness of research recommendations. Suggest additional recommendations warranted, clearly denoting research and monitoring needs that may appreciably improve the reliability of future assessments. Team

The RP agrees with many of the research recommendations in the assessment report. However, we advise that the AT prioritize these, categorically at a minimum, to focus primarily on improving the precision and accuracy of those data that address deficiencies in the assessment model and decision-making. For this reason, we recommend categorizing as high priority the development of a state-wide fishery-independent index of abundance for both life-stages, beyond the "continue existing" programs. This would serve to reduce the dimensionality of the input data (and number of parameters) and allow aggregation of the spatial-temporal issues in the indices. Similarly, the review panel would advise that a high priority research item is to characterize the magnitude of recreational harvest. Finally, given the difficulty to understand stock and fishery status, we believe that the evaluation of alternative reference points should be a top priority. We suggest that the assessment and management group in the agency review the options of fishery-reference points for invertebrate stocks (crustacean and molluscan stocks) that exhibit similar life history and stock recruitment dynamics.

Of medium priority, the RP would recommend evaluating ecosystem and environmental effects on the blue crab stock. Blue crab are a common prey item of many benthivores (Oshima and Leaf, 2018), and patterns in predator abundance likely influence stock dynamics. Further, the influence of environmental events, such as rainfall/freshwater influx, temperature anomalies, or major storms could be evaluated with respect to abundance, or even just availability to surveys and the fishery. We would also recommend investigation of alternative model types, such as a biomass dynamic model. Alternative models could provide corroboration in model results, but may also provide more quantitative reference points. Finally, we believe that exploring genetic stock structure and age and growth determination of blue crab to be of relatively low priority.

3 ADDITIONAL COMMENTS

Overall, we would like to commend the AT for their innovative approach to the assessment of blue crab in the State of North Carolina. The RP does have a few suggestions that might help improve this assessment as well as future assessments. The traffic light approach should have been included within the body of the assessment report to consider a continuity run of a previously established management method alongside the newly developed assessment model. However, it should be noted that the AT did provide the results of a continuity run in comparison to the new model during the peer review. Also, the RP would have appreciated if the model was made available in print and digital form prior to the review workshop in order to evaluate the code, understand mechanics of the analyses, and perform sensitivity runs independently. Finally, the RP would have preferred more time prior to the review in order to allow for a longer period of review.

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10.3 APPENDIX C: Additional Sensitivity Analyses

Per the peer reviewers' request, the working group explored eight candidate models (Model 5 – Model 12), additional to the baseline model (Model 1) and the three ones (Model 2 – Model 4) that are included in the report (Table C1). The fitting to catch data (Figures C1-C3), estimated population size (Figures C7-C8), estimated natural mortality (Figures C9-C10) and fishing mortality (Figures C11-C12) by the two-stage model were quite robust to the assumptions that have been explored, such as natural mortality assumptions, recruitment-spawner relationship, dropping spawner indices, higher catch to account for recreational catch. One exception occurred in Model 8 in which a high input value of natural mortality (M=1.2) resulted in relatively high population size estimates (Figure C8).

Assumption of time-block catchability and the use of combined indices slightly improved the model fitting to abundance indices (Figures C4-C6). Estimated spawner abundance and recruitment showed weak relationship in all candidate models except the Model 4 where a Ricker curve was assumed (Figures C13-C14). Comparing the stock status from all candidate models based on biological reference points that are commonly used (including the maximum sustainable yield based, yield-per-recruit based), an overfished stock and overfishing were suggested in most cases (Table C2).

Tables

Table C1. Additional sensitivity runs (bolded) that have been explored during peer-review workshop.

Model	Features
Model 1 (baseline)	Sex- and stage-specific natural mortality Recruitment free parameter to estimate (lognormal distribution) Time-constant catchability All abundance indices Initial year when catch data start (1995) Sex-specific recruits selectivity to estimate
Model 2	Same as Model 1 except a constant natural mortality to estimate
Model 3	Same as Model 1 except a constant natural mortality to input (M=0.55)
Model 4	Same as Model 1 except recruitment follows a Ricker mode
Model 5	**Same as Model 1 except a time-block catchability (2007)**
Model 6	**Same as Model 1 except dropping P100 indices**
Model 7	**Same as Model 1 except dropping P120 recruit indices**
Model 8	**Same as Model 3 except M=1.2**
Model 9	**Same as Model 1 except using the combined indices**
Model 10	**Same as Model 1 except increasing catch by 15% to account for recreational catch**
Model 11	**Same as Model 1 except dropping all spawner indices (P195 and SEAMAP)**
Model 12	**Same as Model 1 except using fishing year catch data (September 1-August 31)**

Table C2. Stock status determination from sensitivity analysis.

Scenario ID	$N_{SP,\ 2016}$ (10^6)	F_{2016}	$N_{SP,\ MSY}$ (10^6) - threshold	F_{MSY} - threshold	Overfished	Overfishing
Model 1 (baseline)	49.98	1.48	64.48	1.46	Y	Y
Model 2	47.66	1.49	68.54	1.37	Y	Y
Model 3	48.68	1.49	65.1	1.52	Y	N
Model 4	46.03	1.71	79.78	0.94	Y	Y
Model 5	49.47	1.5	63.02	1.46	Y	Y
Model 6	46.22	1.67	67.47	1.32	Y	Y
Model 7	53.5	1.34	71.11	1.31	Y	Y
Model 8	62.13	1.54	59.86	1.84	N	N
Model 9	50.57	1.64	147.63	1.13	Y	Y
Model 10	56.99	1.5	74.41	1.42	Y	Y
Model 11	50.7	1.49	61.38	1.55	Y	N
Model 12	56.57	1.84	74.24	1.39	Y	Y

Figures

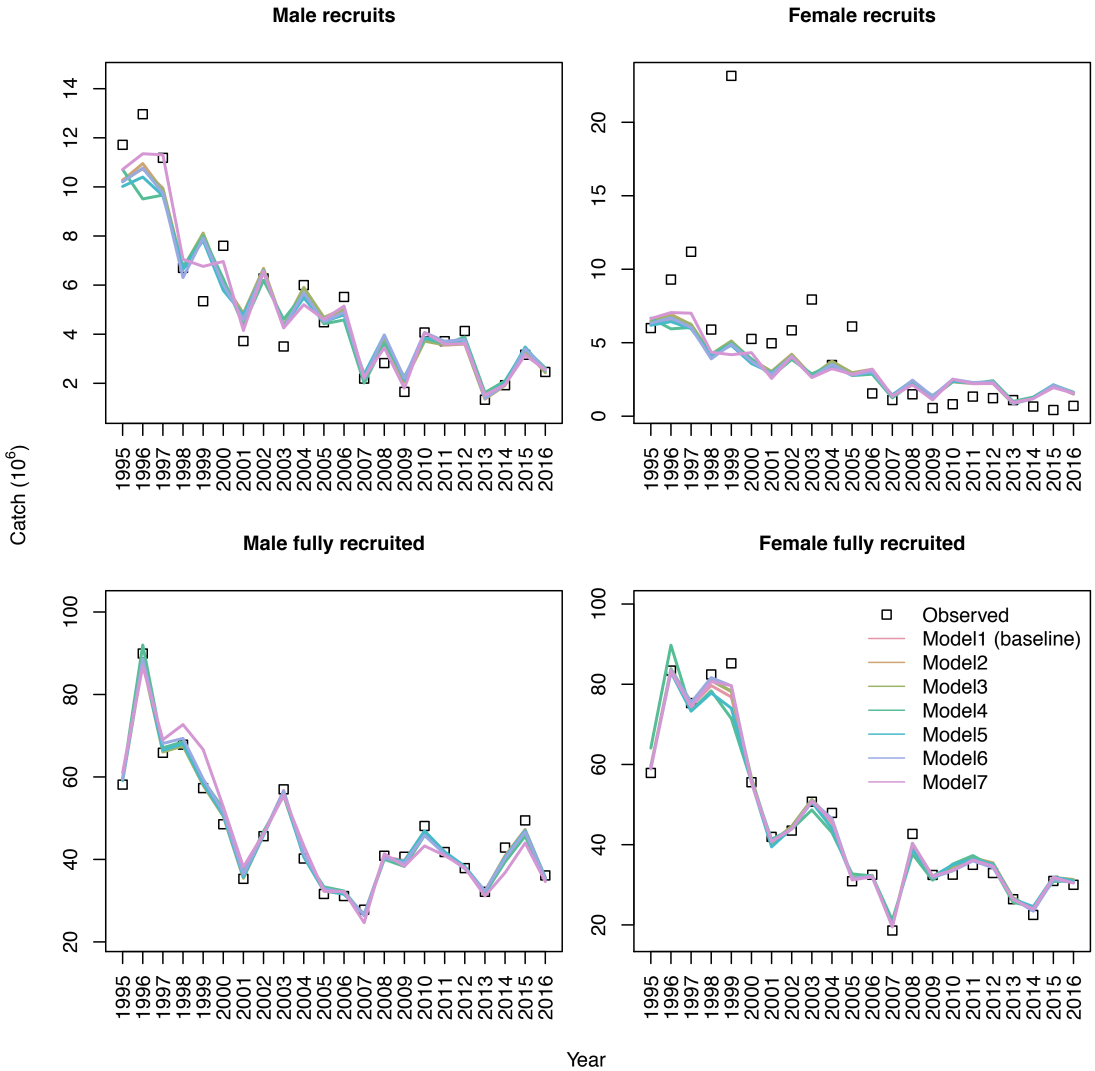

Figure C1. Estimated commercial catch of North Carolina blue crab from candidate models M1-M7, with lines representing posterior mean. The Please refer to Table 1 for the explanation of candidate models.

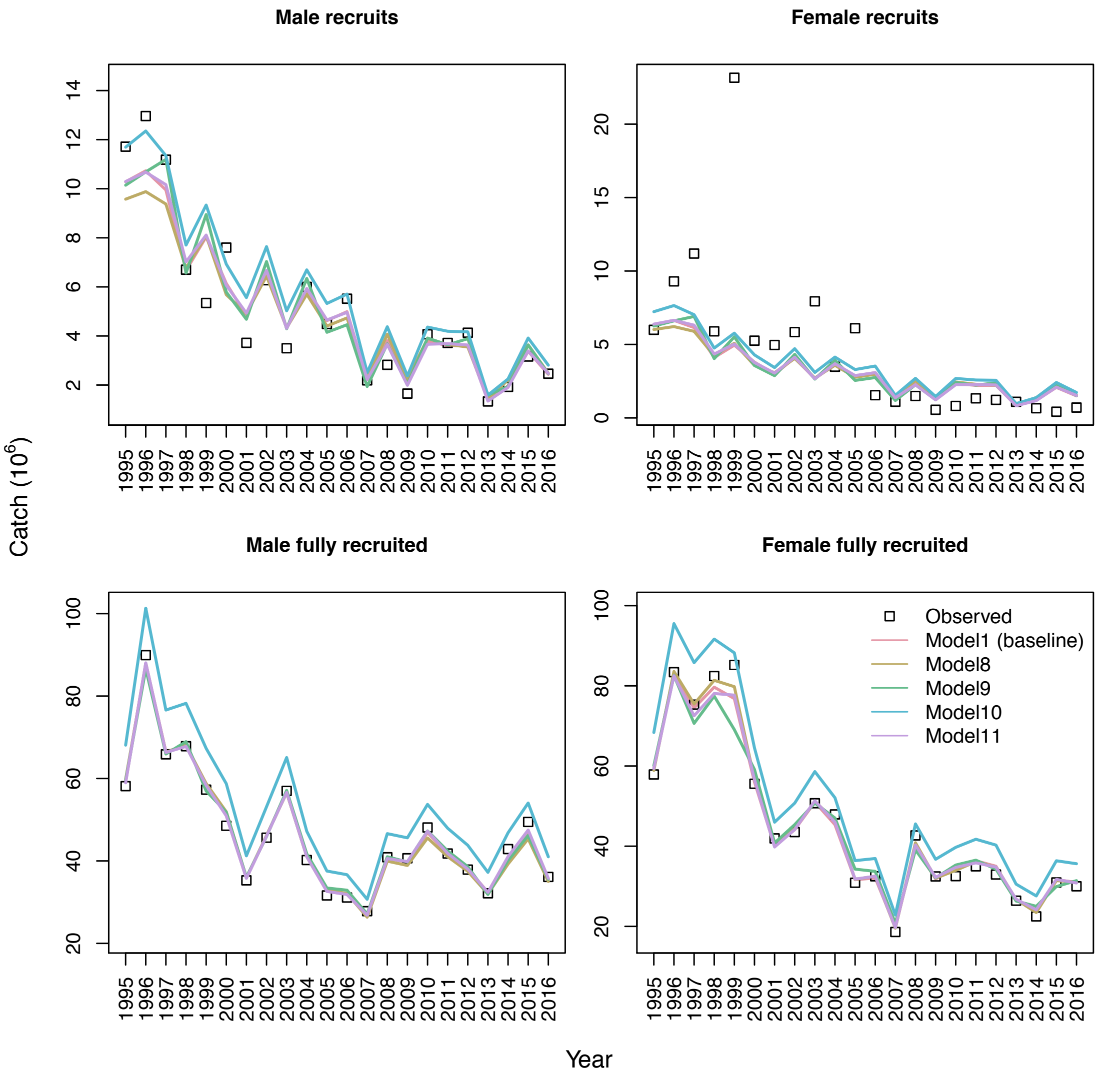

Figure C2. Estimated commercial catch of North Carolina blue crab from candidate models M8-M11, with lines representing posterior mean. The Please refer to Table 1 for the explanation of candidate models.

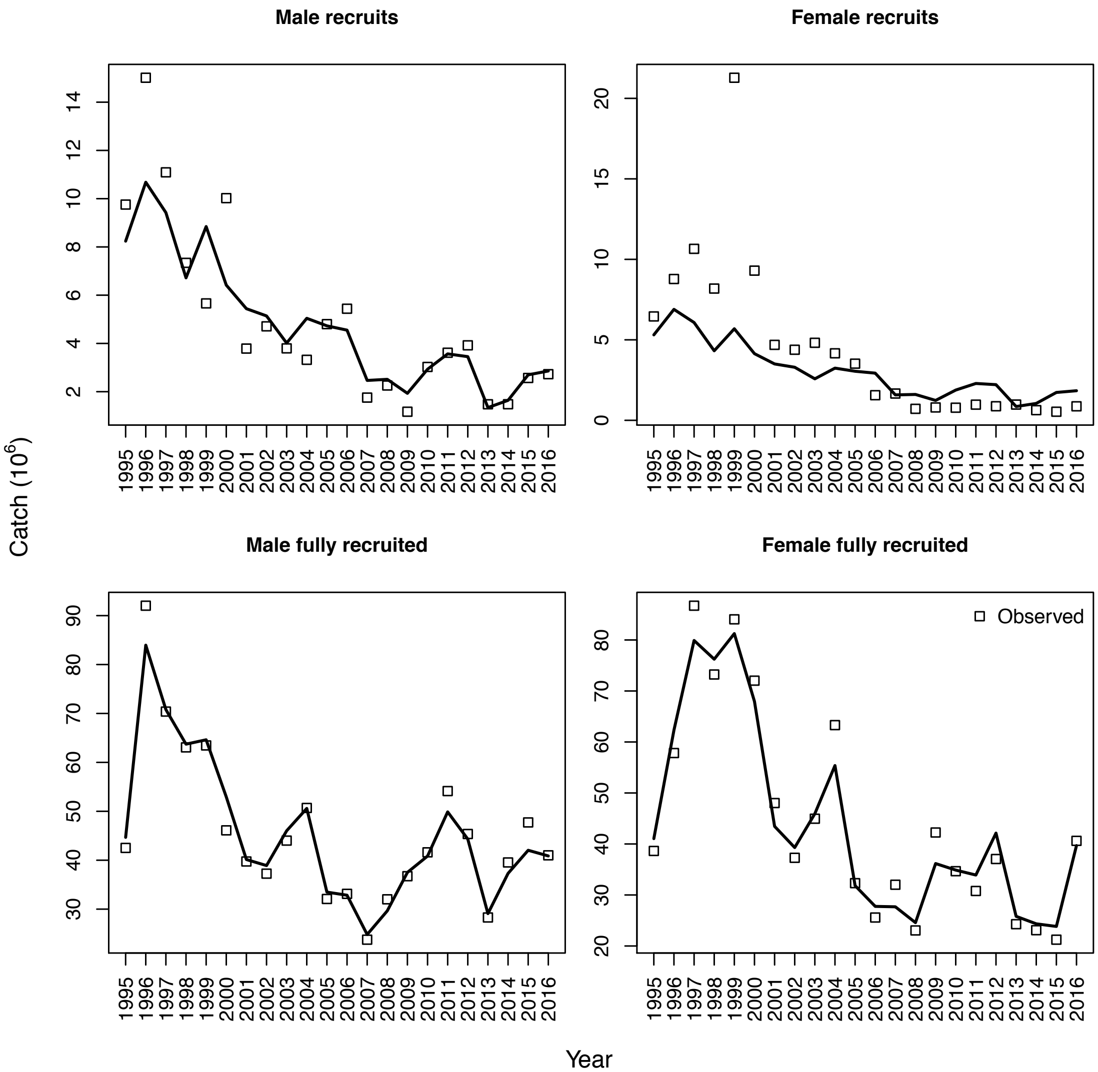

Figure C3. Estimated commercial catch of North Carolina blue crab from candidate models M12, with lines representing posterior mean. The Please refer to Table 1 for the explanation of candidate models.

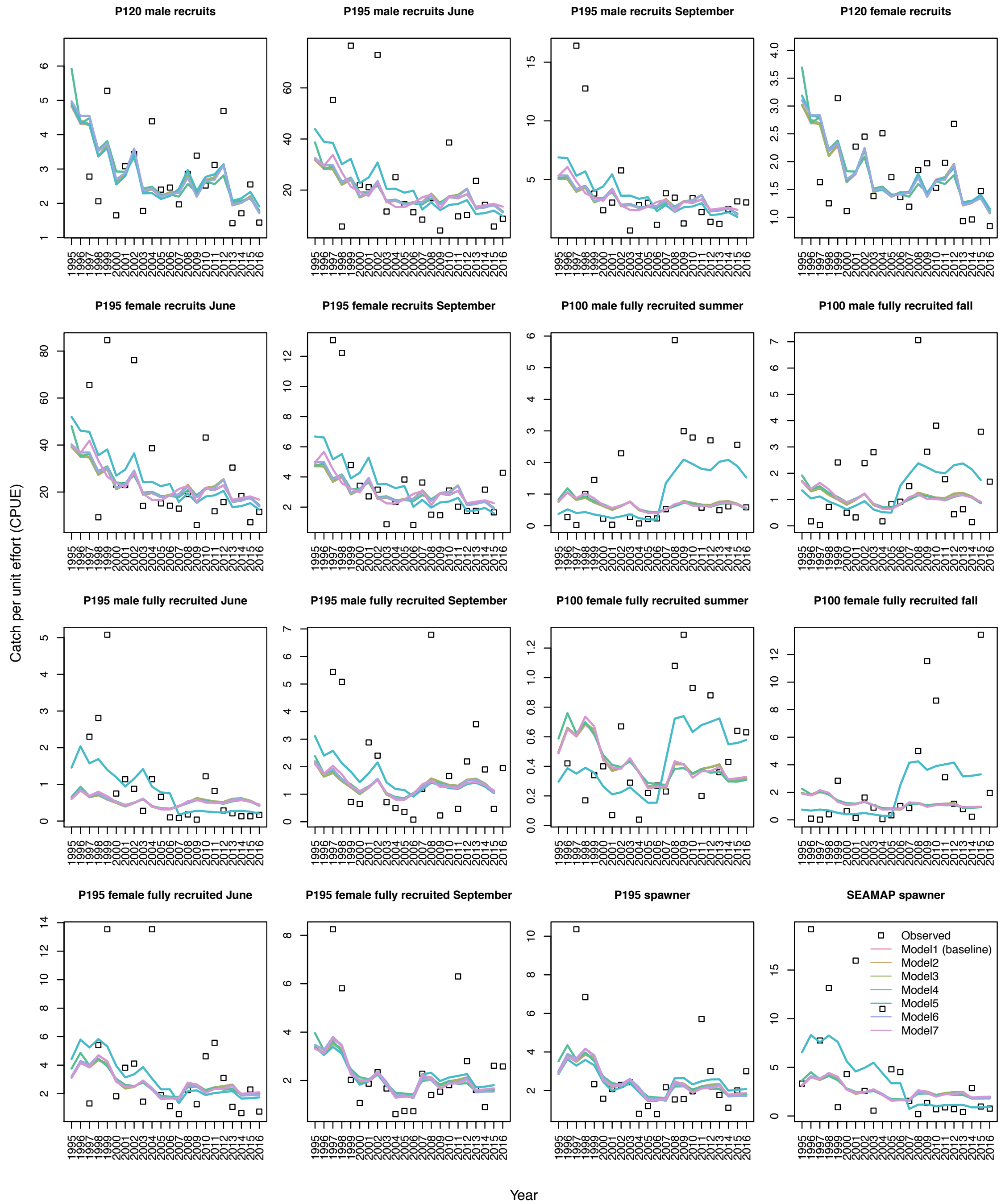

Figure C4. Estimated abundance indices of North Carolina blue crab from candidate models M1-M7, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

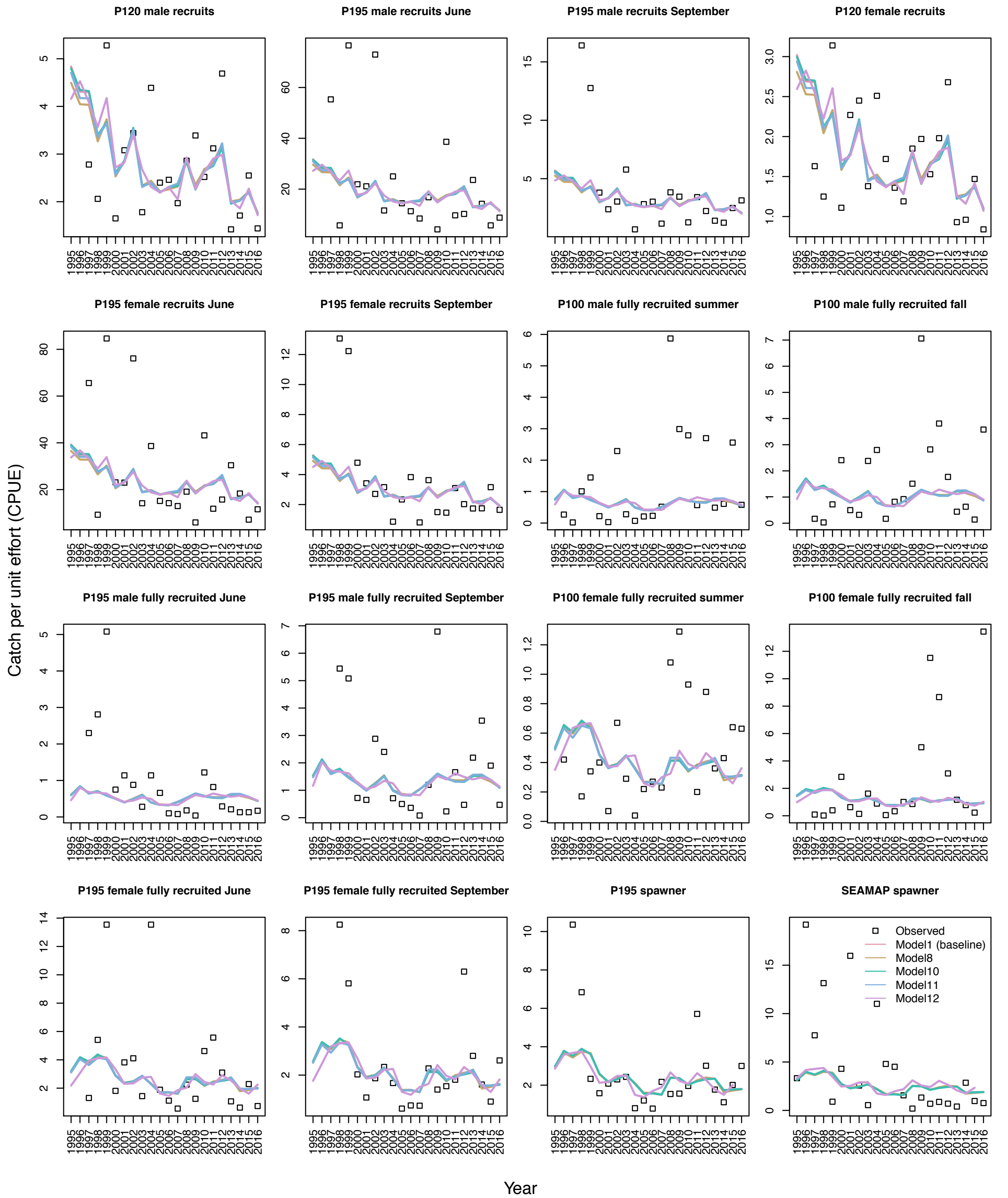

Figure C5. Estimated abundance indices of North Carolina blue crab from candidate models M8, M10-M12, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

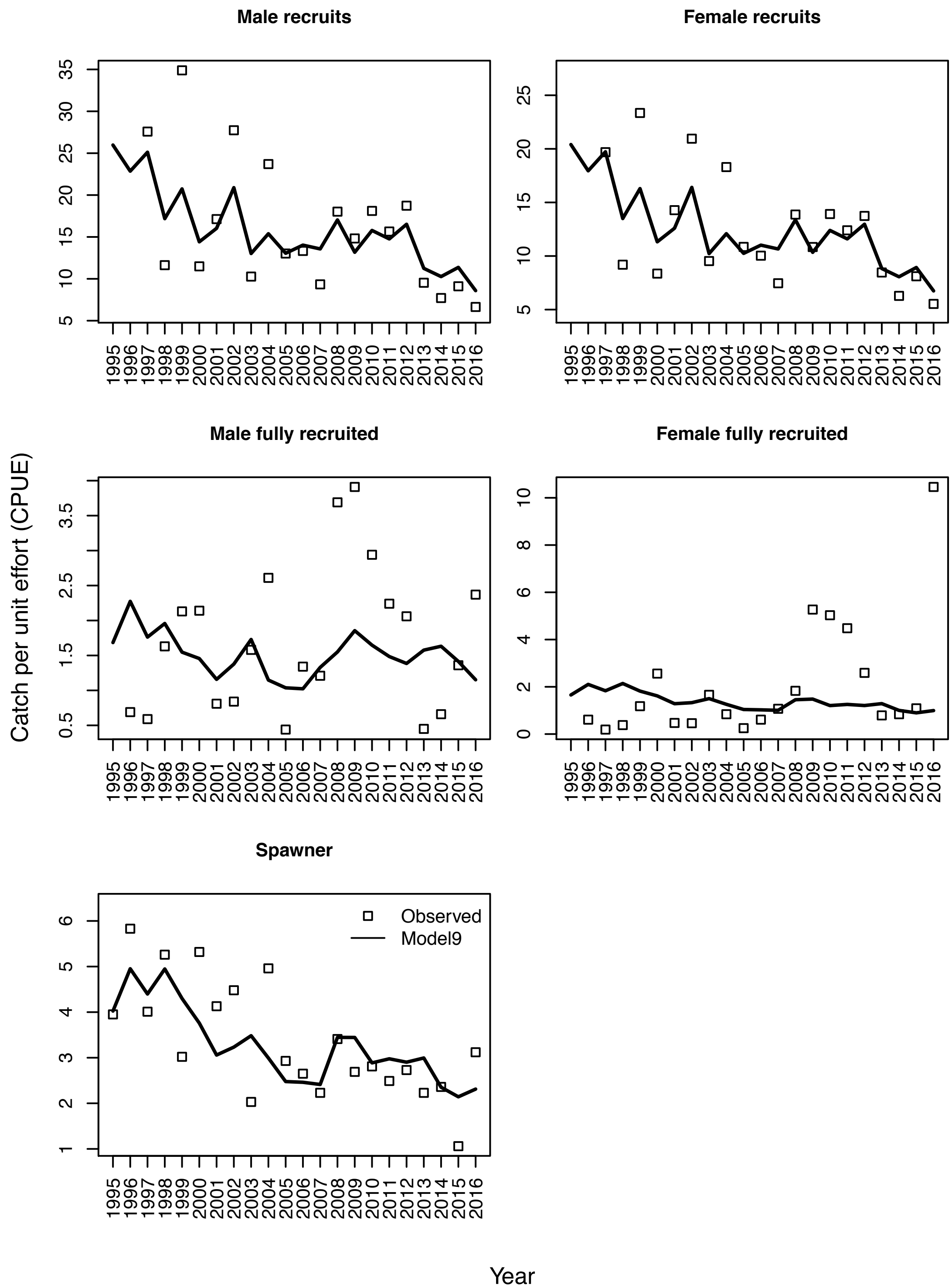

Figure C6. Estimated abundance indices of North Carolina blue crab from candidate models M9, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

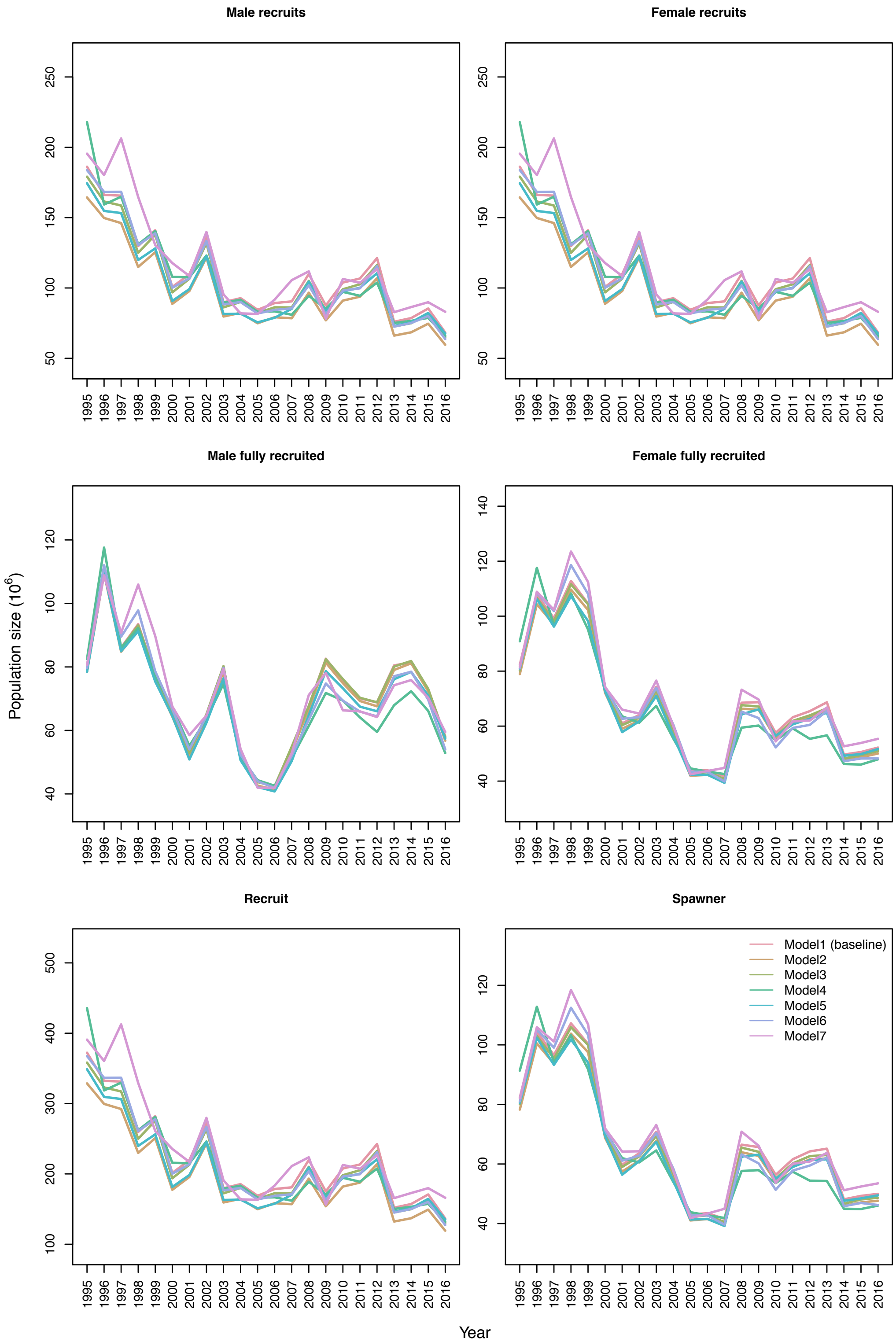

Figure C7. Estimated population size of North Carolina blue crab from candidate models M1-M7, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

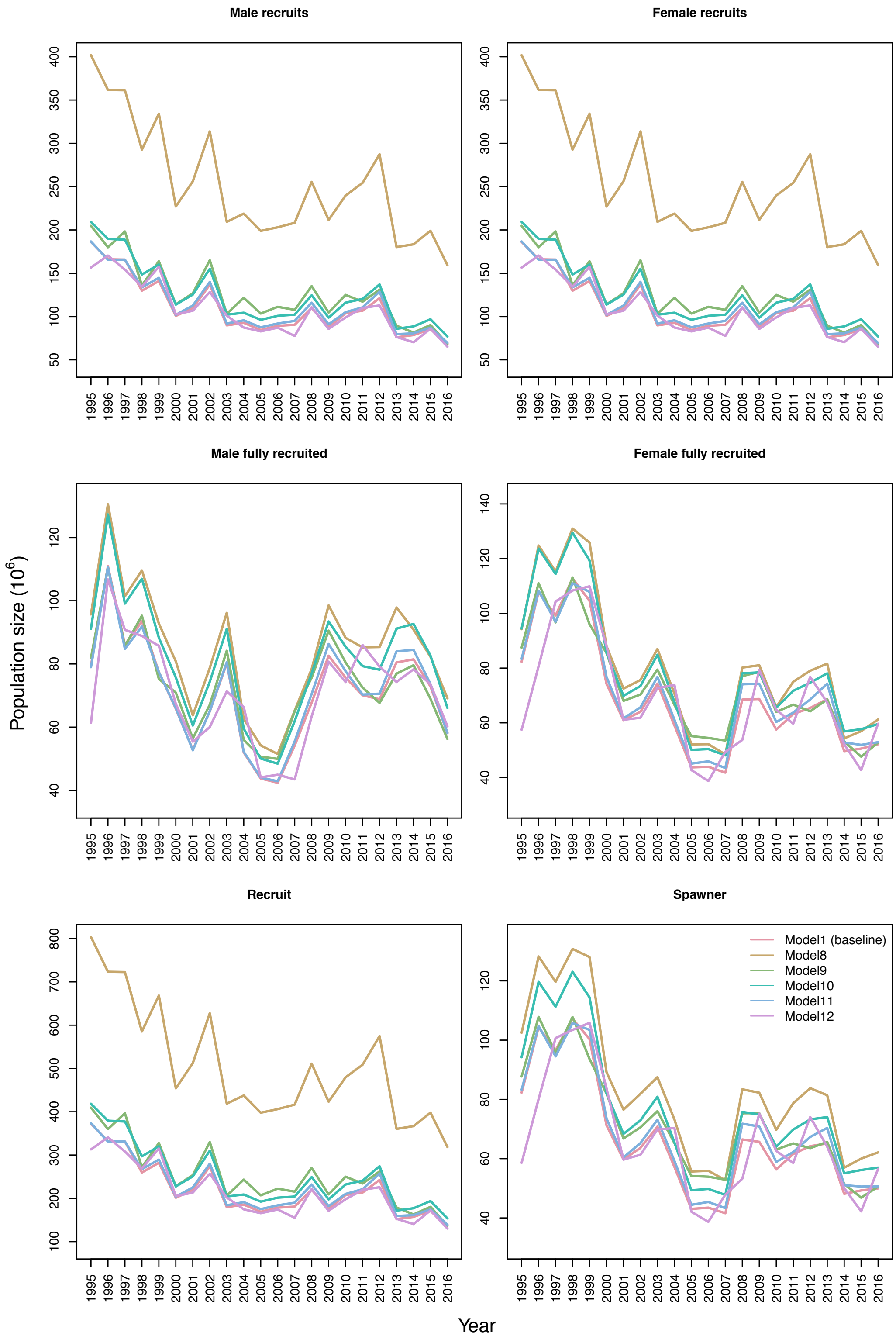

Figure C8. Estimated population size of North Carolina blue crab from candidate models M8-M12, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

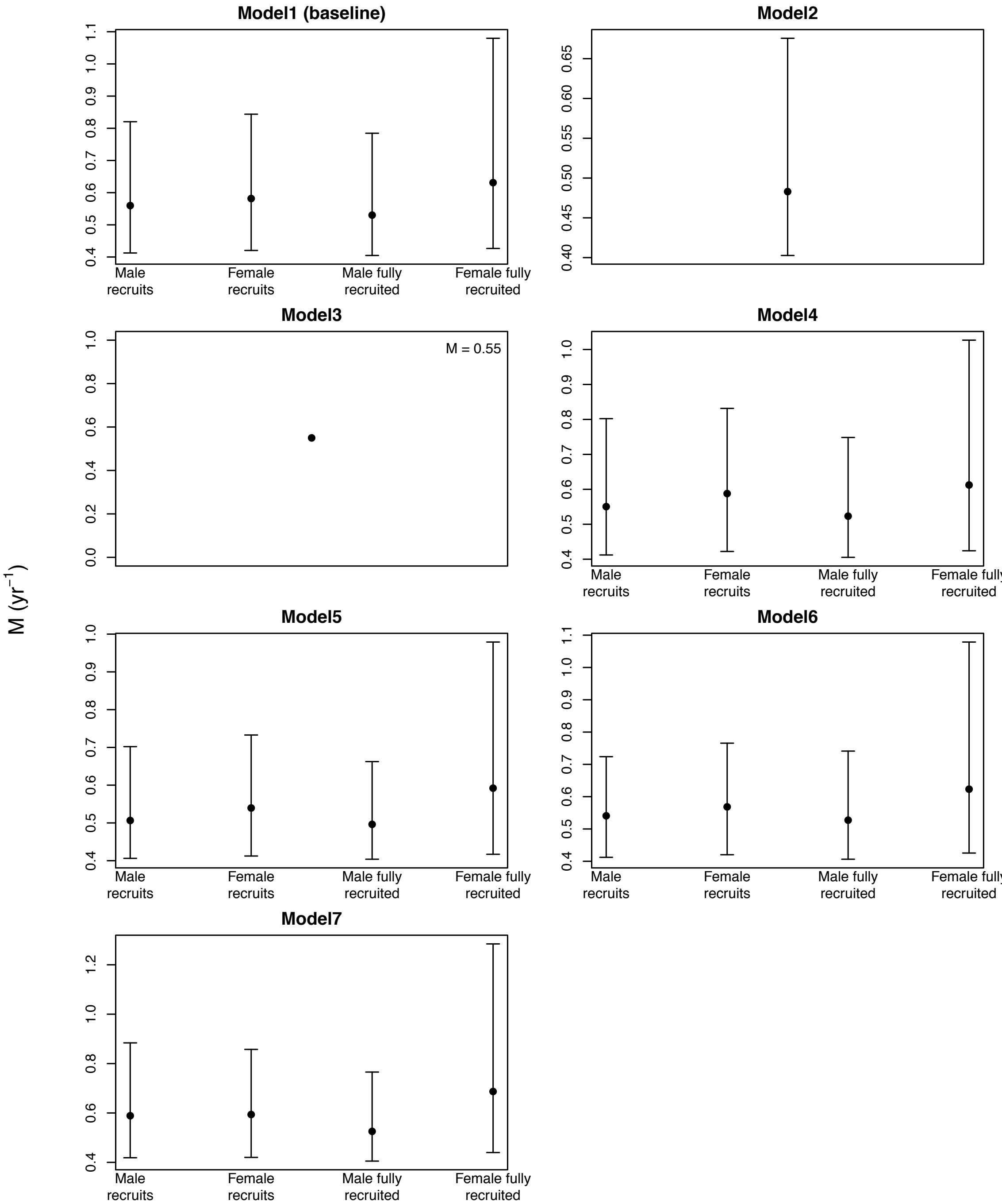

Figure C9. Estimated natural mortality (*M*) from candidate models M1-M7, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

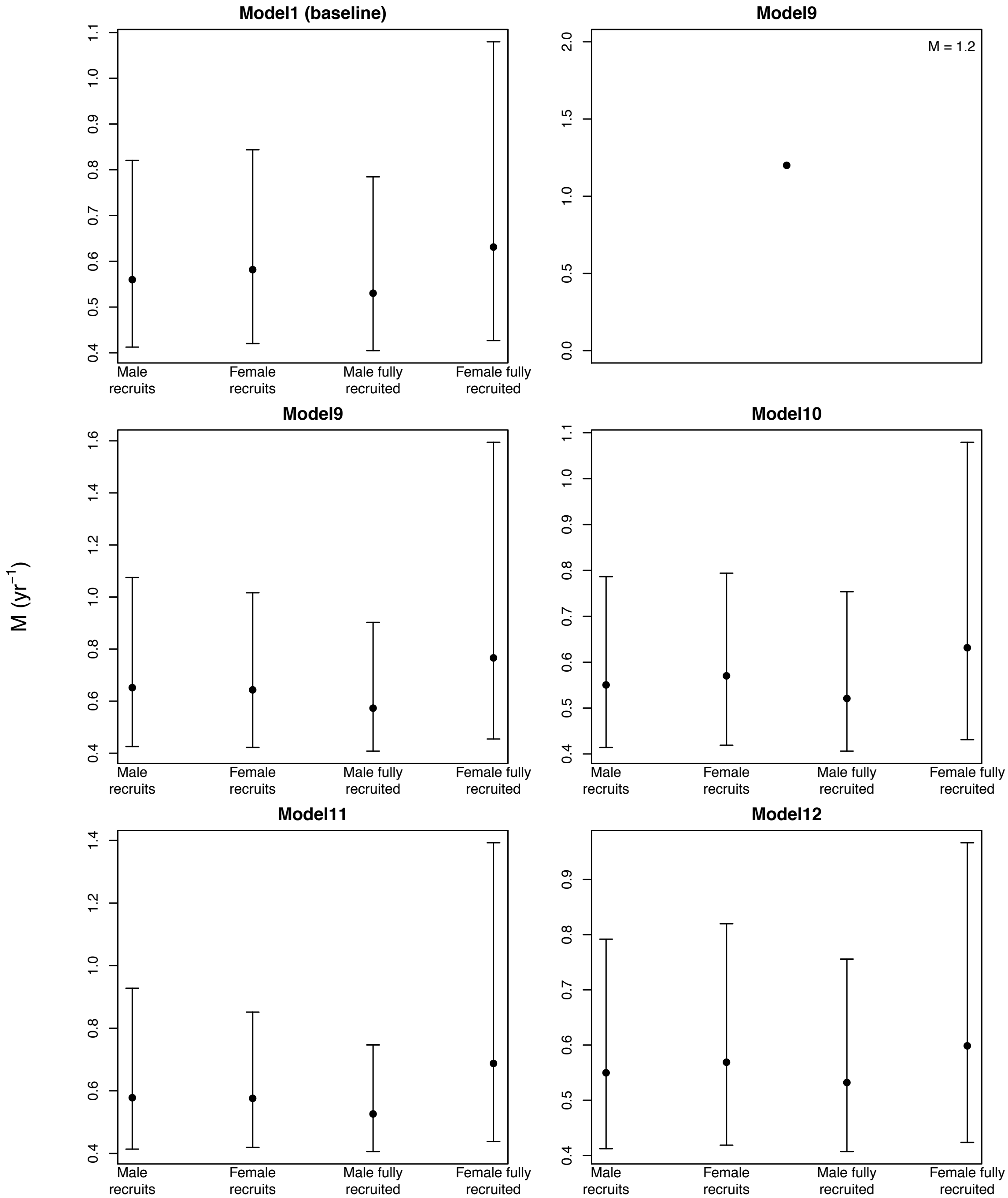

Figure C10. Estimated natural mortality (*M*) from candidate models M8-M12, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

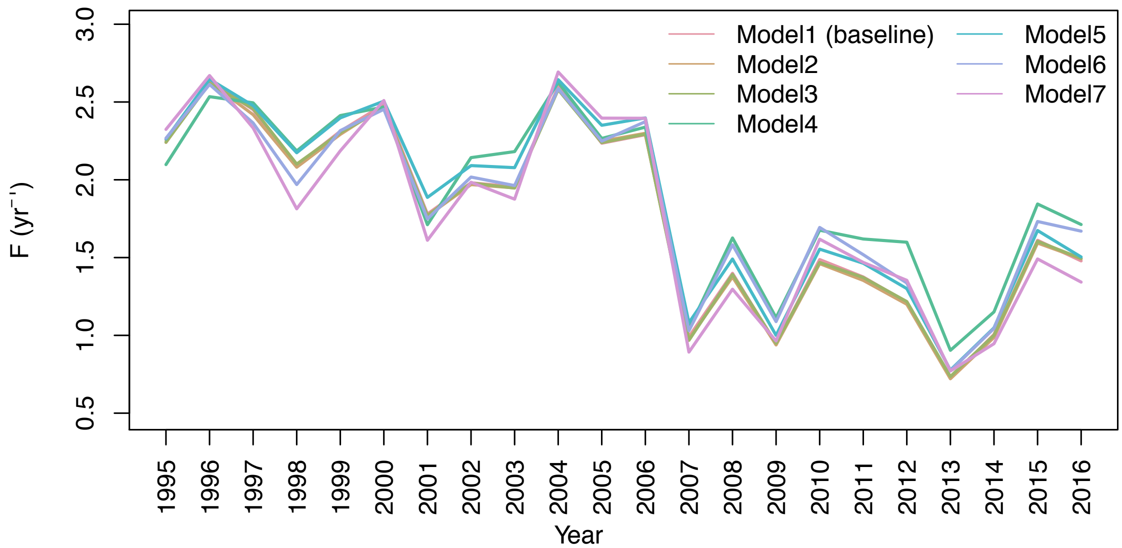

Figure C11. Estimated fishing mortality (*F*) of North Carolina blue crab from candidate models M1-M7, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

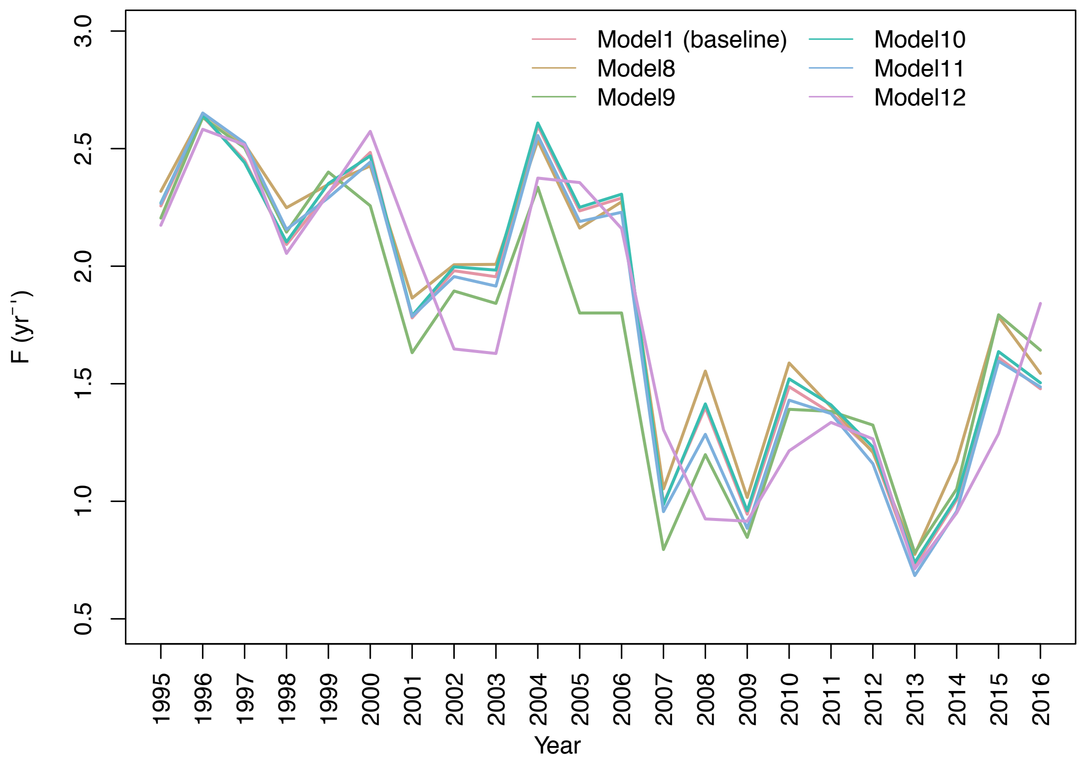

Figure C12. Estimated fishing mortality (*F*) of North Carolina blue crab from candidate models M8-M12, with lines representing posterior mean. Please refer to Table 1 for the explanation of candidate models.

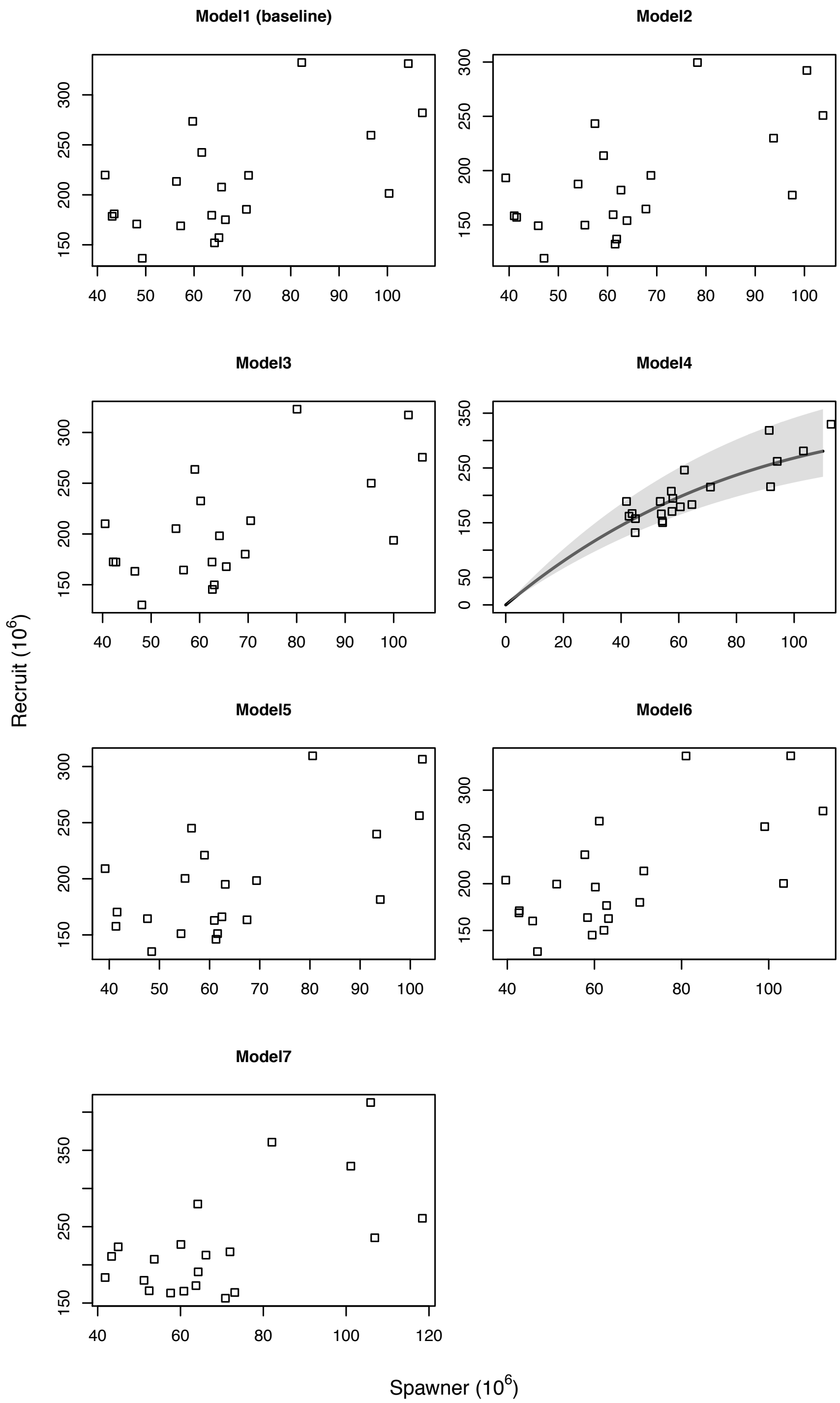

Figure C13. Estimated recruitment and spawner relationships from candidate models M1-M7. Models show the estimated annual average of recruits and spawner stock size except Model 4 which shows the estimated recruits given a spawner stock size assuming a Ricker curve, with lines representing posterior mean and shaded area representing 95% credible interval. Please refer to Table 1 for the explanation of candidate models.

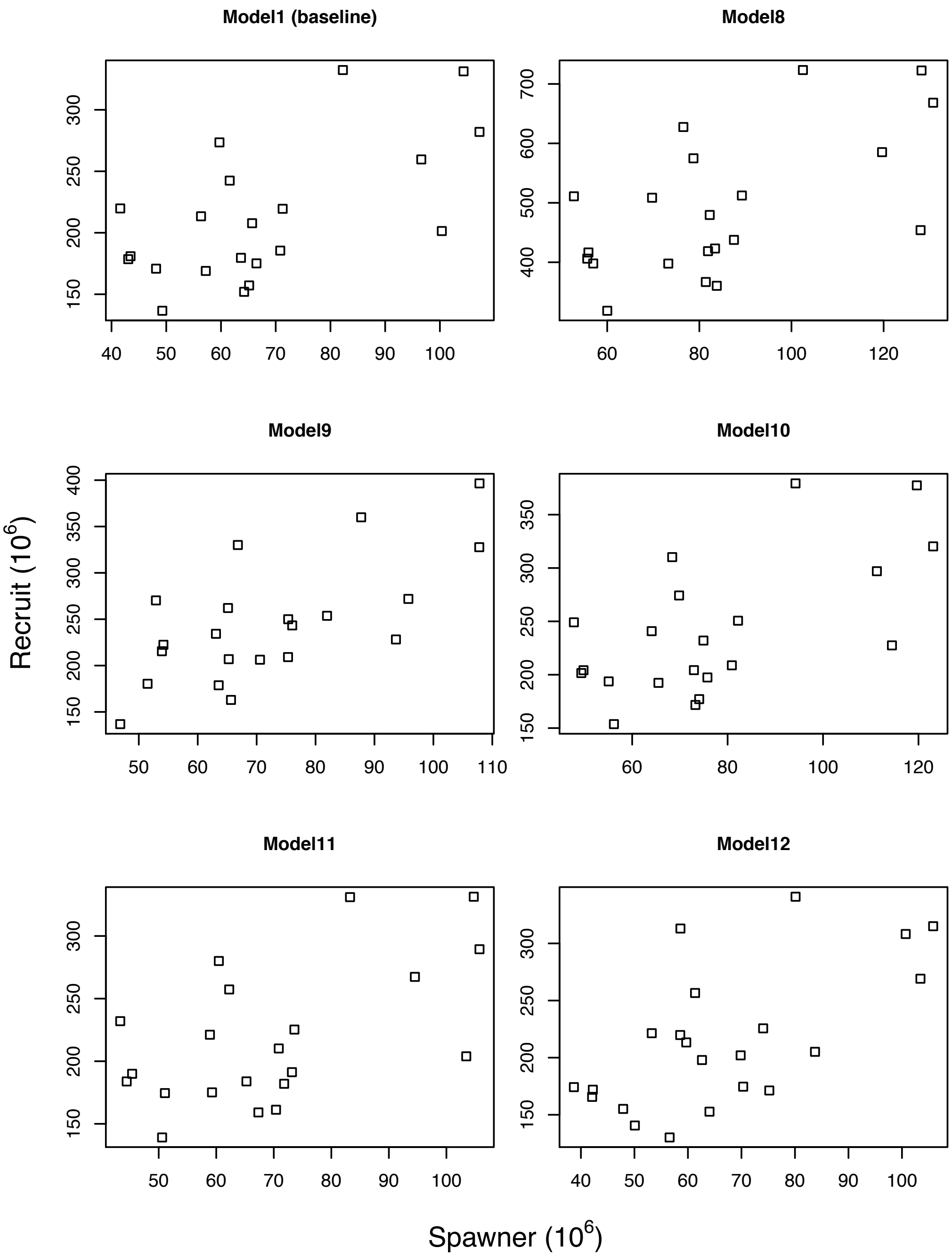

Figure C14. Estimated recruitment and spawner relationships from candidate models M8-M12. Models show the estimated annual average of recruits and spawner stock size Please refer to Table 1 for the explanation of candidate models.

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

May 16, 2018

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Chris Stewart, Shrimp Species Lead
Jason Rock, Shrimp Species Co-Lead
Kevin Brown, Gear Development Biologist
Fisheries Management Section

SUBJECT: Shrimp Fishery Management Plan Workgroup Update

The Shrimp Bycatch Reduction Industry Workgroup met on April 4, 2018 to review the final results of the 2015-2017 gear testing and develop its recommendations to reduce bycatch in the shrimp trawl fishery as mandated by the Shrimp Fishery Management Plan Amendment 1. The workgroup was tasked to initiate a three-year study to test bycatch reduction devices to reduce bycatch to the extent practicable, with a 40 percent target reduction. Promising gear configurations were to be brought back to the Marine Fisheries Commission for consideration for mandatory use in the shrimp trawl fishery. Four of the gears tested met or exceeded the 40 percent target reduction in finfish bycatch while also minimizing shrimp loss. A summary of the results from this gear testing, as well as the workgroup's recommendations can be found in the information paper titled "Shrimp Fishery Management Plan Amendment 1: Consideration of Gear Modifications to Reduce Bycatch in the North Carolina Shrimp Trawl Fishery."

Recommendations from the industry workgroup on bycatch reduction in shrimp trawls that may be adopted by the commission as a result of language in Amendment 1 can be implemented by existing proclamation authority and do not require an amendment to the plan (Marine Fisheries Commission Rule 15A NCAC 03J .0104, 15A NCAC 03L .0101, 15A NCAC 03H .0103(b)). Once final management measures are approved by the commission, the information paper will serve as a Revision to Amendment 1 to the North Carolina Shrimp Fishery Management Plan and will document the management strategy changes and rationale. All other management strategies contained in Amendment 1 will remain in force until another Revision, Supplement or Amendment to the N.C. Shrimp Fishery Management Plan occurs. However, due to the number of existing fishery management plans currently open for review, the division does not recommend a review of the Shrimp Fishery Management Plan until warranted by an amendment or the five-year review in 2020.

Shrimp Fishery Management Plan (FMP) Amendment 1: Consideration of Gear Modifications to Reduce Bycatch in the North Carolina Shrimp Trawl Fishery

April 25, 2018

I. SUBJECT

Investigate gear modifications that could be implemented to reduce bycatch in the shrimp trawl fishery.

II. ORIGINATION

The North Carolina Shrimp Fishery Management Plan (FMP) Amendment 1 and the North Carolina Marine Fisheries Commission (MFC).

III. BACKGROUND

<u>MFC Action</u>
In February 2015, the MFC adopted the Shrimp FMP Amendment 1 and its associated rules (NCDMF 2015). The amendment's primary focus is bycatch reduction in the shrimp trawl fishery. The MFC's preferred management strategy called for three years of industry testing of various gear configurations to reduce bycatch to the greatest extent practicable, with a 40% target reduction goal. Testing is to be conducted by a stakeholder group consisting of fishermen, net/gear manufacturers and scientific/gear specialists, partnered with staff from the North Carolina Division of Marine Fisheries (NCDMF) and North Carolina Sea Grant.

Results should minimize shrimp loss and maximize reduction of finfish bycatch. Promising gear configurations are to be brought back to the MFC for consideration for mandatory use in the shrimp trawl fishery.

Various gear combinations were tested against a control net that used a Florida Fish Eye bycatch reduction device (BRD), a federally-approved turtle excluder device (TED) and a 1 1/2-inch mesh tail bag. Gear combinations tested include:

- Composite/square mesh panels,
- State and federal fisheyes,
- Minimum tailbag mesh size, and
- Reduced bar spacing in TED.

In the development of the final management strategies the MFC passed a motion at its February 2014 business meeting specifying the composition of the stakeholder workgroup and gear testing to be conducted. This was presented to the Shrimp FMP Advisory Committee (AC), as well as the MFC regional and standing advisory committees. In February 2015, the Shrimp FMP Amendment 1 and its rules were adopted by the MFC (see Appendix 1 for supporting motions).

Gear specific management strategies implemented by Amendment 1 not only required the development of the stakeholder group and gear testing, but also required fishermen to use either a

T-90/square mesh tailbag or other applications of square mesh panel (e.g., skylight panel), reduced bar spacing in a TED, or another federal or state certified BRD in addition to existing TED and BRD requirements in all skimmer and otter trawls (Proclamation SH-2-2015; Figure 1). To further address bycatch issues and provide fishermen more flexibility, the MFC also allowed the use of any federally certified BRD in all internal and offshore waters of NC. A maximum combined headrope length of 220 feet was also established in all internal coastal waters that did not have existing maximum headrope requirements to put a cap on fleet capacity as a management tool.

Industry Workgroup

The Shrimp Bycatch Reduction Industry Workgroup was formed in 2015. The workgroup met throughout the gear testing process to discuss results and plan for testing. A list of workgroup members is provided in Appendix 2.

Workgroup meeting summary:

- March 31, 2015 – Reviewed existing and previously completed BRD research and selected designs to be tested by the workgroup. Developed operating procedures and established a schedule and protocols for gear testing in 2015.
- Jan. 25, 2016 – Reviewed first year of testing and plan for the second year. Based on testing results, the workgroup further recommended that new BRD/gear configurations should have an acceptable shrimp loss between 3% to 5%, depending on the reduction in bycatch achieved.
- Jan. 9, 2017 – Reviewed results from the second round of testing and selected gears to be tested in 2017. After focusing on large vessels in estuarine waters the first two years, the workgroup added gear testing for small vessels and testing in the ocean in the third year of the study.
- Jan. 22, 2018 – Review the data and findings from the third year of gear testing.
- April 4, 2018 – Review results from the three years of testing and make recommendations for consideration by the MFC.

NCDMF staff provided the MFC updates on the workgroup's efforts during the testing period. NCDMF staff will present the workgroup's recommendations to the MFC at its May 2018 business meeting.

Industry Gear Testing

To evaluate the effectiveness of the various gear combinations selected by the workgroup, comparative tows were conducted aboard large commercial vessels (>46 ft) in 2015 and 2016; testing in 2017 also included smaller vessels (<45 ft) and in the ocean. Comparative tows consisted of paired net tests where a control net and an experimental net are fished simultaneously. Experimental nets were equipped with the candidate BRD or modification to be tested. Control nets for this project consisted of a typical commercial shrimp two-seam otter trawl with a Florida Fish Eye BRD (state certified), 4-inch bar spacing TED, and 1 1/2-inch stretched mesh tailbag. Headrope length was standardized for both control and experimental nets for each vessel. All experimental nets were calibrated prior to formal field trials to minimize potential net bias and all prototype testing following the National Oceanic and Atmospheric Administration (NOAA) BRD Testing Manual (NOAA 2008). A successful tow was defined as the control and experimental trawl fishing without an indication of problematic events (i.e., crab pots in net) occurring during the tow to impact or influence the fishing efficiency (catch) of one or both nets. Experimental and control nets were also switched from side to side to reduce the potential for side bias and ensure an equal number of successful tows. To eliminate bias associated with the use of a try net (test net pulled for brief periods), the control and experimental nets were tested in the outside nets of the four-barrel (quad) rigs. Gear specification data were collected for both experimental and control nets and included headrope length, mesh size of wing and tail bag, TED type, TED bar spacing, BRD type, location, and duration (tow time). The catch from each net (experimental and control) were sampled by two NCDMF observers. After each paired tow, the entire catch was sampled and the total of weight (kg) of each catch category was recorded. In 2015, only Penaeid shrimp and finfish were recorded; non-shrimp invertebrates, elasmobranchs (sharks/rays), and miscellaneous categories were added for the 2016 and 2017 testing.

Following the completion of each trip, all data were coded and entered into the NCDMF database. Tows were dropped from subsequent analyses if a problematic event (i.e., crab pots in net, hang) was experienced. Paired t-tests (alpha = 0.05) were used to determine whether the catches between the control and experimental nets were significantly different for each category (shrimp and bycatch species). While calibration tows were made prior to testing, some side bias was still assumed in testing. To account for this, test gears were switched between the sides of the vessel throughout testing with the goal of having an even number of tows with the experimental gear on each side of the vessel. When this was not achieved, analyses randomly picked tows so the comparisons would be made with an equal number of tows (with the control and experimental gear) on each side of the vessel. Observed weights were standardized to the target two-hour tow time to adjust for differences in tow times. In 2017, tow-times were standardized to one hour to accommodate the addition of small vessels. The average weight of each net (control and experimental) was computed for each gear and species combination along with the difference in average weight and percent change (percent reduction). A randomization procedure (Manly 2007) was also used to compare catches between control and experimental nets for each gear/species/net combination. The randomization test does not require the data to be normally distributed and does not require tows to be dropped from the analysis. In 2016 and 2017, exploratory analyses were performed to investigate tow side (port versus starboard), time of day (day versus night), and location (2017 only). The results of these analyses indicate that variation in bycatch catch rates is not always due to changes in gear alone; tow side, time of day, and spatial location may also play a role in influencing bycatch catch rates. Generalized linear modeling (GLM) was not used to adjust randomization catch values for potential biases and may differ from those reported in Brown et al. 2017. For a detailed description of the sampling methodology, gear parameters, and full data analysis see Brown et al. (2017, 2018).

Results

A total of 267 comparative tows were made using nine experimental gears during the summer and fall in the Pamlico Sound in 2015 and 2016 (Figure 2). In 2017, a total of 120 comparative tows were made on four experimental gears during the summer and fall in the Pamlico Sound and the nearshore waters of the Atlantic Ocean (Figure 2). Only larger vessels (>46 ft) were used for testing in 2015 and 2016. Testing in 2017 also included smaller vessels (<45 ft). Approximately 98% of the tows (2015-2017) were available for analyses; problematic tows were excluded.

In 2015, only one gear met the 40% target reduction in finfish bycatch set by the MFC (Table 1). The double federal fisheye, 4-inch TED, and 1 7/8-inch tailbag gear combination was found to significantly reduce finfish bycatch by 40.8% based on the t-test results. The randomization test found that finfish bycatch was reduced by 40.1% for this gear combination. While the other experimental gears tested in 2015 failed to meet the 40% target, many of the gears were found to reduce finfish bycatch while minimizing shrimp loss. The composite panel with fish spooker cone significantly reduced finfish bycatch by 25.8% (t-test) to 27.6% (randomization test). Tows made with a 3-inch TED, square mesh panel, and 1 7/8-inch tailbag significantly reduced finfish bycatch by 25.3% (t-test) to 27.5% (randomization test). T-test results indicated the mean weight of finfish bycatch was significantly reduced by 16.2 % using a 3-inch TED and one state fisheye. Of all the gears tested by the workgroup in 2015, the Ricky BRD had the lowest observed reduction in finfish bycatch. Finfish reductions ranged from 4.5% (randomization test) to 6.6% (t-test). The mean weight of shrimp was not significantly different from the control net for all gears tested in 2015.

During the second year of testing, three out of four gears tested met or exceeded the 40% target reduction in finfish bycatch (Table 2). Tows made using a 4-inch TED, double federal fisheyes, and 1 3/4-inch tailbag significantly reduced finfish bycatch by 54.0% (randomization test) to 57.2% (t-test) and had the greatest reduction in finfish bycatch of all the gears tested by the workgroup. Tows made with a 3-inch TED, double federal fisheyes, and 1 3/4-inch tailbag yielded the second highest reduction of the gear combinations tested, reducing finfish bycatch by 44.9% (t-test and randomization test). Finfish bycatch reductions were slightly lower in the fall using one state fisheye, the Virgil Potter BRD, and 1 3/4-inch tailbag gear combination. Finfish bycatch reductions ranged from 43.2% (t-test) to 44.3% (randomization test). While not significant, t-test results indicated the mean weight of shrimp was reduced by 5.5% for this gear combination. A similar gear combination tested in the summer using a slightly smaller mesh tailbag (1 1/2-inch), one state fisheye, and Virgil Potter BRD reduced finfish bycatch 26.9% (t-test) to 28.5% (randomization test). The mean weight of non-shrimp invertebrates and elasmobranchs was not significantly different from the control net for all gears tested in 2016.

While none of the gear combinations tested in 2017 met the 40% target reduction for finfish bycatch (Table 3), the 3-inch TED, double state fisheye, and 1 5/8-inch tailbag did significantly reduce finfish bycatch in the ocean by 32.6% (t-test and randomization test) during summer testing. The mean weight (kg) of shrimp for this gear was also found to be significantly different from the control net, reducing the catch of shrimp by 6.8% (t-test). Testing the same gear combination in the ocean in the fall using a 3-inch TED, double state fisheye, and 1 5/8-inch tailbag did not significantly reduce finfish bycatch and shrimp loss almost tripled the acceptable range recommend by the workgroup. The t-test and randomization test did however indicate the catch of non-shrimp invertebrates and elasmobranchs were significantly reduced by 65.1% and 57.1%, respectfully for this gear combination. The 3-inch TED, single state fisheye, and 1 5/8-inch tailbag experimental gear combination significantly reduced finfish bycatch by 22.8% (t-test) in the summer in Pamlico Sound. However, the mean weights of the other species groups were not significantly different from the control net for this gear. Though not statistically significant, tows made using this gear combination also reduced the shrimp catch by 7.8% (t-test) to 9% (randomization test).

IV. AUTHORITY

§ 113-134. Rules
§ 113-173. Recreational Commercial Gear License
§ 113-182. Regulation 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

15A NCAC 03H .0103 Proclamation Authority of Fisheries Director
15A NCAC 03J .0104 Trawl Nets
15A NCAC 03L .0101 Shrimp Harvest Restrictions
15A NCAC 03L .0103 Prohibited Nets, Mesh Lengths and Areas

V. DISCUSSION

Reducing bycatch in the shrimp trawl fishery and the development of gear configurations that maximize finfish reduction and minimize shrimp loss has been an ongoing task for the Division since the 1980s (NCDMF 2015). The 1992 Atlantic States Marine Fisheries Commission (ASMFC) Weakfish FMP recommended that states implement programs to reduce bycatch mortality of weakfish in the shrimp trawl fishery by 40% (ASMFC 1992). Following this recommendation, the NCDMF conducted a series of independent gear tests as well as tests in cooperation with the shrimp industry. Results from this testing lead to the development of new BRDs and gear modifications to reduce bycatch and North Carolina became the first state to require BRDs in shrimp trawls in 1992. Amendments 3 and 4 to the ASMFC Weakfish FMP later changed the certification requirement to demonstrate a 40% reduction in catch (by number) or a 50% reduction in bycatch mortality of weakfish (ASMFC 1996, 2002). In 2004, Addendum III to Amendment 4 of the ASMFC Weakfish FMP again changed the BRD requirements from a 40% reduction in weakfish by number to 30% by weight (ASMFC 2007). This change was made to compliment the South Atlantic Fishery Management Council (SAFMC) Shrimp FMP and has allowed for more flexible testing and development of BRDs. With the adoption of Amendment 1 to the NC Shrimp FMP, the use of any federally certified BRD in all internal and offshore waters was approved as well as a recommendation to update testing protocols for state BRD certification (NCDMF 2015). These changes, as well as continued industry collaboration, should give fisheries managers more flexibility identifying, developing, and implementing new gears to reduce bycatch.

The use of minimum tailbag mesh regulations has been a common management strategy used by fisheries managers to reduce bycatch. As early as 1949, researchers in North Carolina have examined how larger mesh sizes in tailbags can reduce finfish bycatch in shrimp trawls (Roelofs 1950). Testing conducted by the NCDMF has also shown that larger tailbag mesh sizes and how they are hung (diamond vs. square) can reduce bycatch. Brown (2010) compared the catch rates of shrimp and bycatch in modified trawls with various tailbag mesh sizes in the Neuse River and Pamlico Sound. Experimental nets with 1 3/4-inch tailbags showed significant reductions in Atlantic croaker (16%) and spot (50%) as compared to the control net (standard 1 1/2-inch mesh tail bag); however, no significant difference in the catch of shrimp was detected between the control and experimental net. Experimental nets with a 2-inch tailbag (hung on the square) were found to have even greater reductions for Atlantic croaker (69%) and spot (82%). Results from the 2015-2017 industry field testing also showed that gears with larger tailbag mesh sizes had greater reductions in finfish bycatch than those constructed with smaller mesh tailbags. Of the four gear combinations that met or exceeded the 40% target reduction in finfish bycatch, three of those used a 1 3/4-inch tailbag. Gear combinations using a 1 7/8-inch mesh tailbag were also found to significantly reduce finfish bycatch by 25.3% to 40.8% (randomization test data: 27.5% to 40.1%).

NOAA Fisheries has required the use of TEDs since 1992 to reduce the number of strandings and incidental takes of sea turtles (NCDMF 2015). TEDs have also been shown to reduce the bycatch of smaller finfish and invertebrates in both otter and skimmer trawls (Broome 2011; Price and Gearhart 2011). Currently, federal law mandates a 4-inch maximum TED bar spacing between grids. Broom et al. 2011, found that reduced TED grid spacing was very effective at reducing finfish bycatch while maintaining minimal shrimp loss. The authors also noted a noticeable reduction in large rays, sharks, jellyfish and horseshoe crabs in the 2-inch reduced grid TED. Of the gear combinations tested by the workgroup that met the 40% reduction in finfish bycatch, only one used a 3-inch TED. Results from both the t-test and randomization test indicated that tows made using double federal fisheyes, 1 3/4-inch tailbag, and 3-inch bar TED reduced finfish bycatch by 44.9% and only had a 4.9% loss of shrimp. Tows made with double state fisheyes, 1 5/8-inch mesh tailbag, and 3-inch TED bar spacing were also found to significantly reduce the catch of elasmobranchs by approximately 57% (t-test and randomization test) in the fall ocean fishery. Raborn et al. (2012) noted that the use of TEDs in the Gulf of Mexico Penaeid shrimp fishery reduced the catch of blacknose sharks by 94% and bonnethead sharks by 31%. The authors further note, that smaller coastal sharks, such as Atlantic sharpnose sharks, may be more effectively excluded by TEDs with reduced bar spacing. Both t-test and randomization tests indicated the catch of non-shrimp invertebrates was significantly reduced (by 65.1%) for tows made using double state fisheyes, 1 5/8-inch tailbag, and a 3-inch TED. When used in combination with larger tailbag mesh sizes (>1 1/2-inch), TEDs with reduced bar spacing appear to be very effective at reducing the bycatch of elasmobranchs and non-shrimp invertebrates in the ocean.

With the adoption of Amendment 1 the MFC also mandated the use of an additional federal or state certified BRD in all skimmer and otter trawls. Most fishermen have opted to use an additional state fisheye due to their low cost and ease of installation (K. Brown. NCDMF, personal communication). State fisheyes are a diamond shaped BRD (sometimes oval) that measure 5 1/2 inches by 6 1/2 inches, which provides an opening of approximately 20 square inches (Figure 3). The use of two state fisheyes provides approximately 40 total square inches of opening. Federal fisheye must have a minimum opening of 36 square inches; however, all federal fisheyes tested by the workgroup were built with a margin of error that expanded the opening to 40 square inches (Figure 3). Thus, the use of two federal fisheyes provided approximately 80 square inches of opening. Of the four gear combinations that met or exceeded the 40% target reduction in finfish bycatch, three used double federal fisheyes. Gear combinations tested using double federal fisheyes were found to reduce finfish bycatch by 54% (randomization test) to 57.2% (t-test), whereas those using two state fisheyes only reduced finfish bycatch by as much as 32.6% (t-test and randomization test). The additional 40 square inches of opening gained using double federal fisheyes appears to provide greater escapement of finfish than the use of double state fisheyes. Overall shrimp loss of gears using double federal fisheyes was comparable to losses of gears using double state fisheyes. However, tows made with double federal fisheyes with the addition of a float (Ricky BRD) had shrimp losses nearly double the industry recommendation and only minimal reduction in finfish bycatch. Gear combinations that incorporated two federal fisheyes and large mesh tailbags (1 3/4-inch or greater) appeared to provide the greatest reductions in finfish bycatch and further allow fishermen to use the same gear in both state and federal waters within the Exclusive Economic Zone (EEZ).

While all the gear combinations tested resulted in reductions in finfish bycatch, it is hard to specify what element of the design made the largest contribution. Conversely, it is also hard to identify what design elements played the greatest role in minimizing shrimp loss. However, results from the industry field testing do indicate that small modifications in gear configuration such as TED bar spacing and tailbag mesh size can significantly impact gear performance. The addition of a 1 3/4-inch tailbag to the Virgil Potter BRD was found to reduced finfish bycatch an additional 15.8% (randomization test) to 16.3% (t-test) as compared to same gear rigged with a 1 1/2-inch tailbag. These reductions could be even greater with the addition of a 3-inch reduced grid TED. Nevertheless, the individual contribution of each modification cannot be quantified until further testing is done to test each specific design element of the gear combinations that met the 40% target reduction in finfish bycatch. Future testing should also incorporate design elements of gear combinations that did not meet the 40% target reduction in finfish bycatch. While several of those tested failed to meet the target, many obtained finfish bycatch reductions ranging from 25% to 30%. Thus, it is important to note that these reductions in bycatch are in addition to the 30% reduction in finfish mandated by the federal BRD certification process and gears that met the MFC’s 40% finfish bycatch reduction achieved nearly twice the federal requirements for reducing bycatch. Results from the industry gear testing should further encourage the use and development of new and innovative BRD designs.

Management decisions based on the results of the industry gear testing should not only consider which gear combinations had the greatest reduction in finfish bycatch, but should also consider vessel size as well as their contribution to the overall landings. In the last ten years (2007-2016), vessels greater than 55 feet made up roughly 30% of North Carolina’s shrimp trawl fleet and landed 73% of the total shrimp landings (Table 4). In North Carolina’s estuarine waters, roughly 67% of the vessels were 45 feet or less in length and harvested 17% of the total estuarine shrimp landings. Of the gear combinations that met the 40% reduction in finfish bycatch, vessel size ranged from 68 to 88 feet in the Pamlico Sound (Tables 1-2). Thus, it’s important to note that observed finfish reductions obtained on larger vessels may not be directly applied to smaller vessels that operate in smaller waterbodies. The mandated use of untested gears on smaller boats could negatively impact gear performance and efficiency due to differences in tow times and haul-back practices. Furthermore, bycatch reductions achieved on smaller vessels should not be directly applied to larger vessels until further testing can be done. Future gear testing should include a wide variety of vessels across multiple areas throughout the state to determine how seasonal differences in species abundance, movement associated with life stage, and environmental factors influence gear performance.

All the necessary data do not currently exist to adequately quantify the overall reduction in bycatch gained by the mandated use of the gear combinations tested that met the 40% target reduction in finfish bycatch. Thus, management decisions should further consider the full extent of the social and economic factors that may impact the shrimp trawl fishery and its associated gears. Costs associated with purchasing and installing gear could become cost prohibitive making it no longer feasible for fishermen to continue in the fishery once their current gear configuration is obsolete; these costs could further be amplified for vessels using double and four-barrel rigs. To lessen these costs, a phase-in period should be considered. Furthermore, the mandated use of untested gear combinations could further hinder the development and voluntary use of new BRDs. While gears such as the Ricky BRD did not meet the 40% target reduction in finfish, it is important to note that these gears were developed by fishermen and had promising results. Industry involvement is a key factor in not only the development and testing of new gears, but the overall acceptance of new gears. Murry et al. (1992) noted that shrimpers prefer to reduce bycatch because of the additional culling time, damage it causes to the quality of shrimp, and the extra weight in the tailbags which can reduce trawl door spread and fuel efficiency. Without acceptance from the public, the overall reduction in bycatch could be minimal if gear specific regulations are difficult to enforce. Regulations based on vessel length would be easier to enforce than those based on total combined headrope length. Vessel length can be determined from the Commercial Fishing Vessel Registration. Gear specific regulations should also consider user group (recreational, commercial) and gear type (otter trawl, skimmer trawl, crab trawl) in addition to vessel size. Recommendations from the industry workgroup on bycatch reduction in shrimp trawls that may be adopted by the MFC do not require an amendment and could be implemented by existing proclamation authority. Based on the motion passed at their February 2014 business meeting, the MFC may consider promising gear configurations that were tested by the industry workgroup for mandatory use in the shrimp trawl fishery. Management decisions based on industry collaboration, such as the work summarized in this paper, should provide further insight on solutions that limit bycatch while minimizing shrimp loss.

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VIII. THE FOUR GEAR COMBINATIONS THAT ACHEIVED AT LEAST A 40% REDUCTION IN FINFISH BYCATCH

1) Double federal fisheyes, 1 7/8-inch tailbag, and 4-inch TED
   + Significantly reduces finfish bycatch (t-test: -40.8%, randomization test: -40.1%)
   + Net gain in shrimp observed; however, not significant (t-test: +1%, randomization test: +2.2%)
   + Reduces culling time due to less bycatch
   + Implements actions of Amendment 1 to the Shrimp FMP
   - Costs associated with purchasing and installing gear (+$600 per net)
   - Untested on smaller vessels, skimmer trawls, and in the Atlantic Ocean

2) Double federal fisheyes, 1 3/4-inch tailbag, and 4-inch TED
   + Significantly reduces finfish bycatch (t-test: -57.2%, randomization test: -54.0%)
   + Reduces non-shrimp invertebrate bycatch; however, not significant (t-test: -15.7, randomization test: -4.9%,)
   + Reduces culling time due to less bycatch
   + Implements actions of Amendment 1 to the Shrimp FMP
   - Shrimp losses greater than 5%; however, not significant (t-test: -12.1%, randomization test: -16.2%)
   - Costs associated with purchasing and installing gear (+$600 per net)
   - Untested on smaller vessels, skimmer trawls, and in the Atlantic Ocean

3) Double federal fisheyes, 1 3/4-inch tailbag, and 3-inch TED
   + Significantly reduces finfish bycatch (t-test and randomization test: -44.9%)
   + Observed shrimp losses less than 5%; however, not significant (t-test and randomization test: -4.9%)
   + Reduces non-shrimp invertebrate bycatch; however, not significant (t-test and randomization test: -13.3%)
   + Reduces elasmobranch bycatch; however, not significant (t-test and randomization test: -18.6%)
   + Potential reductions in debris and jellyfish
   + Reduces culling time due to less bycatch
   + Implements actions of Amendment 1 to the Shrimp FMP
   - Costs associated with purchasing and installing gear (+$1,250 per net)
   - Potential fouling issues in areas and times of high grass concentrations
   - Untested on smaller vessels, skimmer trawls, and in the Atlantic Ocean

4) Single state fisheye, 1 3/4-inch tailbag, and Virgil Potter BRD
   + Significantly reduces finfish bycatch (t-test: -43.2%, randomization test: -44.3%)
   + Reduces culling time due to less bycatch
   + Implements actions of Amendment 1 to the Shrimp FMP
   - Costs associated with purchasing and installing gear (+$800 per net)
   - Shrimp losses greater than 5%; however, not significant (t-test: -5.5%, randomization test: -5.8%)
   - Untested on smaller vessels, skimmer trawls, and in the Atlantic Ocean

IX. RECOMMENDATION

Shrimp Industry Bycatch Reduction Workgroup

- Does not want to go on record recommending a range of acceptable shrimp loss; if finfish bycatch reduction is significant, a larger range could be acceptable (beyond range used by workgroup of 3-5%).
- Does want to recommend continued collaborative bycatch reduction research, specifically continuance of the N.C. Shrimp Bycatch Reduction Industry Workgroup, requesting that funding from gear testing possibly come from surplus funds from increased license fees (i.e., Commercial Fishing Resources Fund). Industry continues to be willing to provide in-kind contributions.
- Does endorse for use on otter trawls fishing in inside waters (in areas where a combined head rope of 90-feet or greater is allowed as identified in the Shrimp FMP; Figure 4) the four combinations of bycatch reducing gears that met the target of 40% bycatch reduction, but specifically recommends:
- Use of the combination gear of double Federal fisheyes, 4-inch TED and 1 ¾-inch tailbag, again, in inside waters where an otter trawl with a combined head rope of 90-feet or greater is allowed. (Specific intent is not to have this change applied to other areas open to otter trawls, channel nets, and skimmer trawls until further bycatch reduction testing has been completed.)
- Recommends the N.C. Division of Marine Fisheries explores valid survey techniques to gather information on current bycatch reduction devices being used by industry.

Summary of Additional Comments from Absentee Workgroup Members*

- Some members gave blanket support.
- Would like consideration of a phase-in period.
- Had reservations on more than 5 percent shrimp loss.
- Support not setting arbitrary shrimp loss levels.
- Support for reduced bar spaced TED, but defer to those working affected areas.
- The double federal fisheyes and 1 ¾-inch tailbag produced desired goal and should not be a burden for affected boats.
- 1 ¾-inch tailbag not tested on smaller boats
    - Anecdotal testing showed shrimp loss on 21/25 and 16/20 count shrimp
- More testing on small vessels
    - Allow more time to find working combination for small vessels

**See Appendix 3 for complete correspondences received from absentee workgroup members on proposed recommendations.*

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Table 1. Results from the paired t-test and randomization test of the five experimental gears tested during 2015. Mean weight of catch data reported in kg. Values in bold indicate significant p-values (alpha = 0.05). Gears in grey met or exceeded the 40% reduction target for finfish bycatch.

Season / Waterbody	Vessel size (ft)	Gear	Tailbag (in.)	TED (in.)	Species group	T-test N	T-test Control Mean	T-test Exp. Mean	T-test % Change	T-test p-value	Randomization* N	Randomization* Control Mean	Randomization* Exp. Mean	Randomization* % Change	Randomization* p-value
Summer / Pamlico Sd.	68	Composite panel, spooker cone	1 1/2	4	Finfish	44	178.1	132.1	-25.8	< **0.001**	60	177.3	128.4	-27.6	< **0.001**
					Shrimp	44	64.3	63.9	-0.7	0.754	60	67.3	65.2	-3.1	0.776
Summer / Pamlico Sd.	75	Single state fisheye	1 1/2	3	Finfish	16	107.3	90.0	-16.2	**0.029**	19	112.8	89.8	-20.4	0.217
					Shrimp	16	49.6	46.0	-7.4	0.078	19	48.2	45.5	-5.6	0.739
Summer / Pamlico Sd.	75	Single state fisheye, square mesh panel	1 7/8	3	Finfish	40	104.8	78.2	-25.3	< **0.001**	51	102.3	74.1	-27.5	**0.007**
					Shrimp	40	65.7	64.4	-1.9	0.309	51	67.3	65.2	-3.0	0.775
Summer / Pamlico Sd.	88	Ricky BRD	1 1/2	4	Finfish	10	110.6	103.3	-6.6	0.503	15	100.0	95.5	-4.5	0.793
					Shrimp	10	35.3	31.8	-9.9	0.449	15	35.4	33.3	-6.1	0.728
Summer / Pamlico Sd.	88	Double federal fisheye	1 7/8	4	Finfish	25	90.0	53.3	-40.8	< **0.001**	32	88.3	52.9	-40.1	< **0.001**
					Shrimp	25	61.3	61.9	1.0	0.778	32	60.6	61.9	2.2	0.862

** Generalized linear modeling (GLM) was not used to adjust randomization catch values for potential biases and may differ from those reported in Brown et al. 2017.*

Table 2. Results from the paired t-test and randomization test of the five experimental gears tested during 2016. Mean weight of catch data reported in kg. Values in bold indicate significant p-values (alpha = 0.05). Gears in grey met or exceeded the 40% reduction target for finfish bycatch.

Season / Waterbody	Vessel size (ft)	Gear	Tailbag (in.)	TED (in.)	Species group	T-test N	T-test Control Mean	T-test Exp. Mean	T-test % Change	T-test p-value	Randomization* N	Randomization* Control Mean	Randomization* Exp. Mean	Randomization* % Change	Randomization* p-value
Summer/ Pamlico Sd.	68	Single state fisheye, Virgil Potter BRD	1 1/2	4	Finfish	30	146.3	106.9	-26.9	**< 0.001**	33	149.4	106.9	-28.5	**0.005**
					Shrimp	30	62.6	68.8	9.9	**0.050**	33	61.8	67.0	8.5	0.696
					Invertebrates┼	10	3.3	2.7	-18.8	0.384	33	1.0	0.8	-18.8	0.681
					Elasmobranchs	7	5.3	5.9	11.1	0.589	33	1.1	1.2	11.1	0.912
Summer / Pamlico Sd.	75	Double federal fisheye	1 3/4	4	Finfish	6	201.5	86.3	-57.2	**0.001**	23	164.5	75.6	-54.0	**< 0.001**
					Shrimp	6	23.0	20.2	-12.1	0.215	23	28.1	23.6	-16.2	0.280
					Invertebrates┼	6	7.2	6.1	-15.7	0.081	23	5.4	5.1	-4.9	0.833
					Elasmobranchs	6	1.8	2.6	45.8	0.509	23	2.1	2.5	18.8	0.573
Summer / Pamlico Sd.	75	Double federal fisheye	1 3/4	3	Finfish	30	115.4	63.6	-44.9	**< 0.001**	30	115.4	63.6	-44.9	**0.007**
					Shrimp	30	27.0	25.7	-4.9	0.435	30	27.0	25.7	-4.9	0.706
					Invertebrates┼	30	2.1	1.8	-13.3	0.418	30	2.1	1.8	-13.3	0.601
					Elasmobranchs	27	1.8	1.4	-18.6	0.404	30	1.6	1.3	-18.6	0.568
Fall / Pamlico Sd.	68	Single state fisheye, Virgil Potter BRD	1 3/4	4	Finfish	20	189.0	107.0	-43.2	**< 0.001**	25	172.3	96.1	-44.3	**0.001**
					Shrimp	20	33.1	31.3	-5.5	0.055	25	31.3	29.5	-5.8	0.691
					Invertebrates┼	25	0.0	0.0	n/a	n/a	25	0.0	0.0	n/a	n/a
					Elasmobranchs	25	0.0	0.1	n/a	n/a	25	0.0	0.0	n/a	n/a

** Generalized linear modeling (GLM) was not used to adjust randomization catch values for potential biases and may differ from those reported in Brown et al. 2017.*

┼ *Non-shrimp invertebrates*

Table 3. Results from the paired t-test and randomization test of the five experimental gears tested during 2017. Mean weight of catch data reported in kg. Values in bold indicate significant p-values (alpha = 0.05). Gears in grey met or exceeded the 40% reduction target for finfish bycatch.

Season / Waterbody	Vessel size (ft)	Gear	Tailbag (in.)	TED (in.)	Species group	T-test N	T-test Control Mean	T-test Exp. Mean	T-test % Change	T-test p-value	Randomization** N	Randomization** Control Mean	Randomization** Exp. Mean	Randomization** % Change	Randomization** p-value
Summer / Pamlico Sd.	44	Single state fisheye	1 1/2	3	Finfish	*	*	*	*	*	5	12.3	12.9	5.1	0.732
					Shrimp	*	*	*	*	*	5	18.7	17.3	-7.8	0.827
					Invertebrates┼	*	*	*	*	*	5	4.9	6.8	38.8	0.281
					Elasmobranchs	*	*	*	*	*	4	0.2	0.4	75.0	0.487
Summer / Pamlico Sd.	40	Single state fisheye	1 5/8	3	Finfish	20	34.6	26.7	-22.8	**0.019**	22	34.9	27.8	-20.4	0.341
					Shrimp	20	12.1	11.2	-7.8	0.294	22	11.6	10.6	-9.0	0.556
					Invertebrates┼	18	2.3	2.1	-6.1	0.692	22	2.1	2.1	-0.4	0.993
					Elasmobranchs	*	*	*	*	*	3	0.3	0.1	-80.0	0.397
Summer / Ocean	40	Double state fisheye	1 5/8	3	Finfish	30	146.0	98.5	-32.6	**< 0.001**	30	146.0	98.5	-32.6	**0.002**
					Shrimp	30	2.9	2.7	-6.8	**0.039**	30	2.9	2.7	-6.6	0.598
					Invertebrates┼	30	17.2	15.9	-7.6	0.086	30	17.2	15.9	-7.6	0.505
					Elasmobranchs	29	3.0	2.5	-16.3	0.184	30	2.9	2.4	-16.7	0.425
Fall / Ocean	35	Double state fisheye	1 5/8	3	Finfish	30	57.5	54.9	-4.6	0.670	30	57.5	54.9	-4.6	0.890
					Shrimp	30	9.8	8.3	-14.9	**< 0.001**	30	9.8	8.3	-14.8	0.365
					Invertebrates┼	30	8.2	2.9	-65.1	**0.001**	30	8.2	2.9	-65.1	**< 0.001**
					Elasmobranchs	28	4.4	1.9	-57.1	**0.009**	29	4.3	1.8	-57.3	**0.014**
Fall / Ocean	60	Double federal fisheye	1 5/8	3	Finfish	30	75.6	97.7	29.3	0.204	30	75.6	97.7	29.3	0.250
					Shrimp	30	17.3	15.7	-9.0	**0.002**	30	17.3	15.1	-12.5	0.234
					Invertebrates┼	25	2.2	2.7	21.9	0.276	30	2.3	2.9	25.1	0.455
					Elasmobranchs	15	1.3	1.0	-24.3	0.271	28	0.9	0.7	-24.5	0.360

** Tows were dropped from analysis due to the low number of matched pairs.*
*** Generalized linear modeling (GLM) was not used to adjust randomization catch values for potential biases.*
┼ *Non-shrimp invertebrates*

Table 4. North Carolina commercial shrimp trawl landings (all species) by vessel length and waterbody, 2007-2016 (NC Trip Ticket Program).

Waterbody	Vessel length	Vessels (10-year)			Trips (10-year)			Landings (10-year)		
	(Feet)	(Total number)	(% Total)	(Avg.)	(Total number)	(% Total)	(Avg.)	(Total number)	(% Total)	(Avg.)
Estuarine	0-15	99	2.6	10	294	0.7	29	74,368	0.1	7,437
	16 to 30	1,648	43.9	165	16,996	42.1	1,700	3,036,958	5.8	303,696
	31 to 45	765	20.4	77	10,597	26.3	1,060	5,839,690	11.2	583,969
	46 to 55	287	7.6	29	3,187	7.9	319	4,728,222	9.1	472,822
	> 55	956	25.5	96	9,275	23	928	38,563,295	73.8	3,856,329
State Ocean (0-3 mi)	0-15	9	0.7	2	21	0.1	4	30,802	0.2	5,134
	16 to 30	265	21	27	3,194	18.3	319	620,296	4.2	62,030
	31 to 45	292	23.2	29	4,640	26.6	464	1,708,624	11.6	170,862
	46 to 55	174	13.8	17	3,874	22.2	387	1,990,624	13.6	199,062
	> 55	519	41.2	52	5,721	32.8	572	10,333,660	70.4	1,033,366
Federal Ocean (3-200 mi)	0-15	3	2.5	3	5	1.6	5	1,289	0.1	1,289
	16 to 30	5	4.1	1	17	5.4	4	2,518	0.2	629
	31 to 45	13	10.7	2	31	9.9	5	11,109	1.1	1,852
	46 to 55	14	11.6	2	43	13.7	7	39,582	3.9	6,597
	> 55	86	71.1	10	217	69.3	24	968,016	94.7	107,557
Total (all waters)	0-15	111	2.2	7	320	0.6	525	106,459	0.2	6,262
	16 to 30	1,918	37.4	80	20,207	34.8	19	3,659,771	5.4	152,490
	31 to 45	1,070	20.8	41	15,268	26.3	842	7,559,424	11.1	290,747
	46 to 55	475	9.3	18	7,104	12.2	587	6,758,428	9.9	259,940
	> 55	1,561	30.4	54	15,213	26.2	273	49,864,971	73.4	1,719,482

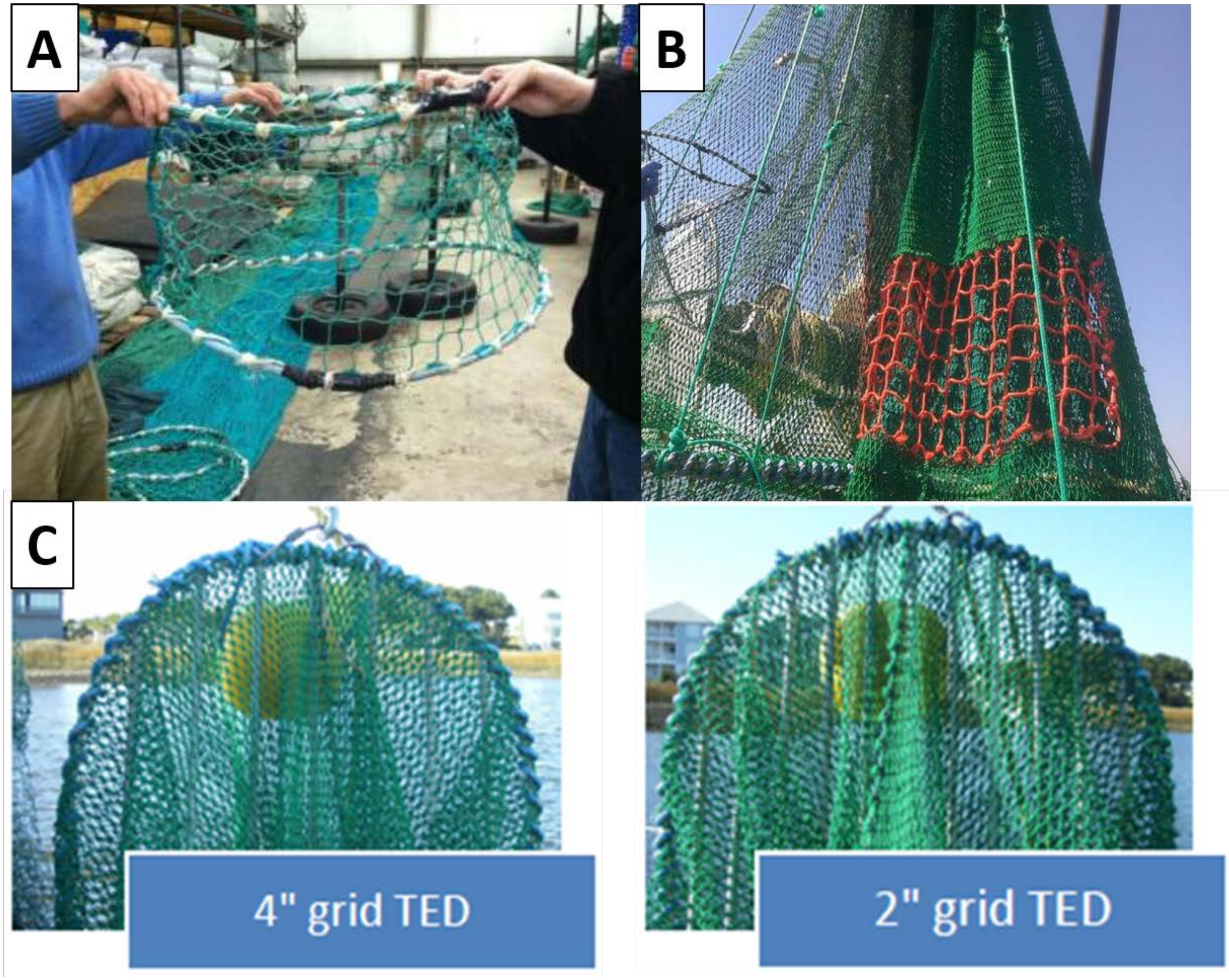

Figure 1. Newly approved BRDs as part of Amendment 1 to the NC Shrimp FMP: A) T-90 BRD, B) square mesh panel (skylight panel), and C) reduced bar spacing turtle excluder device (2-inch grid TED).

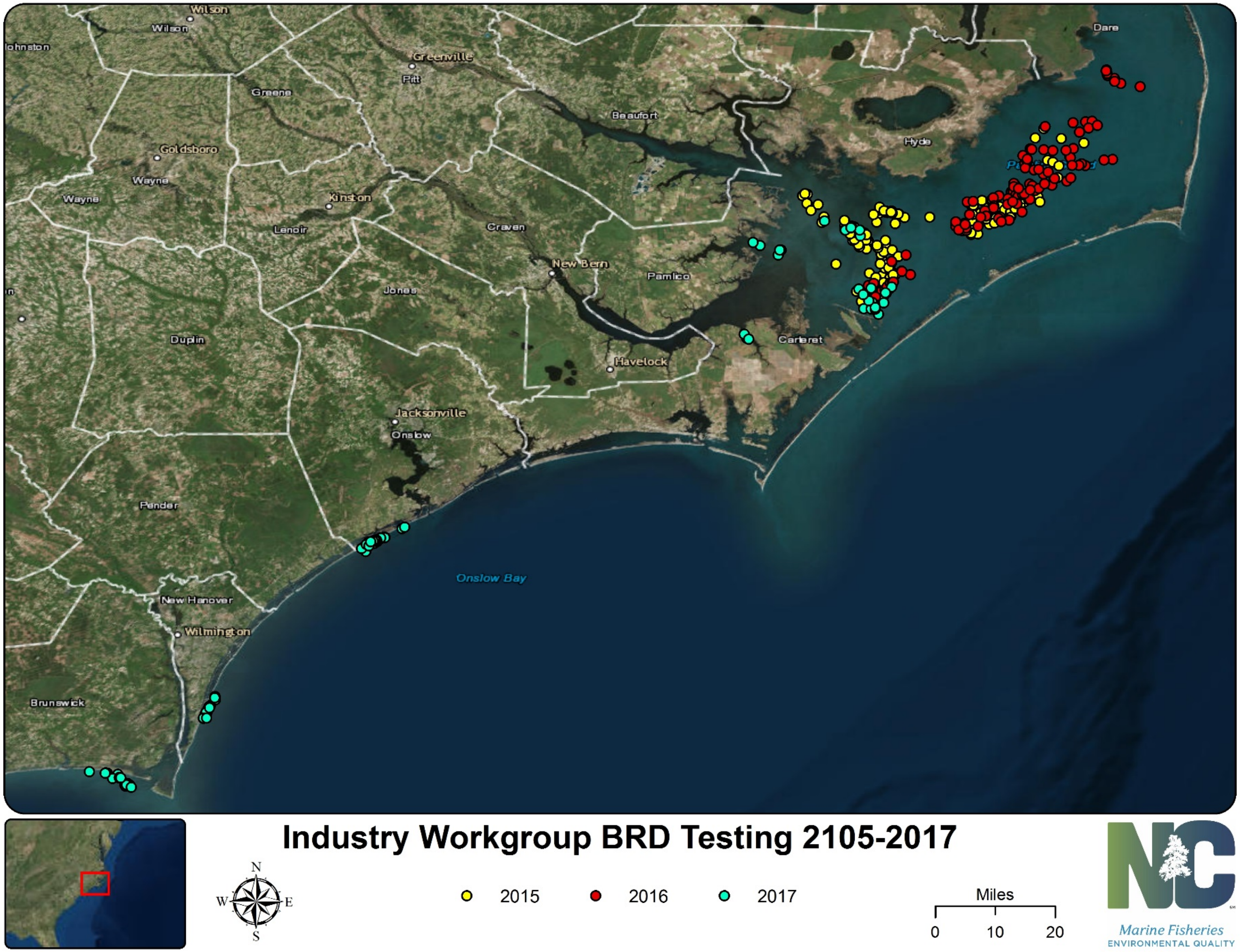

Figure 2. Location of industry workgroup shrimp trawl gear testing (all gears), 2015-2017.

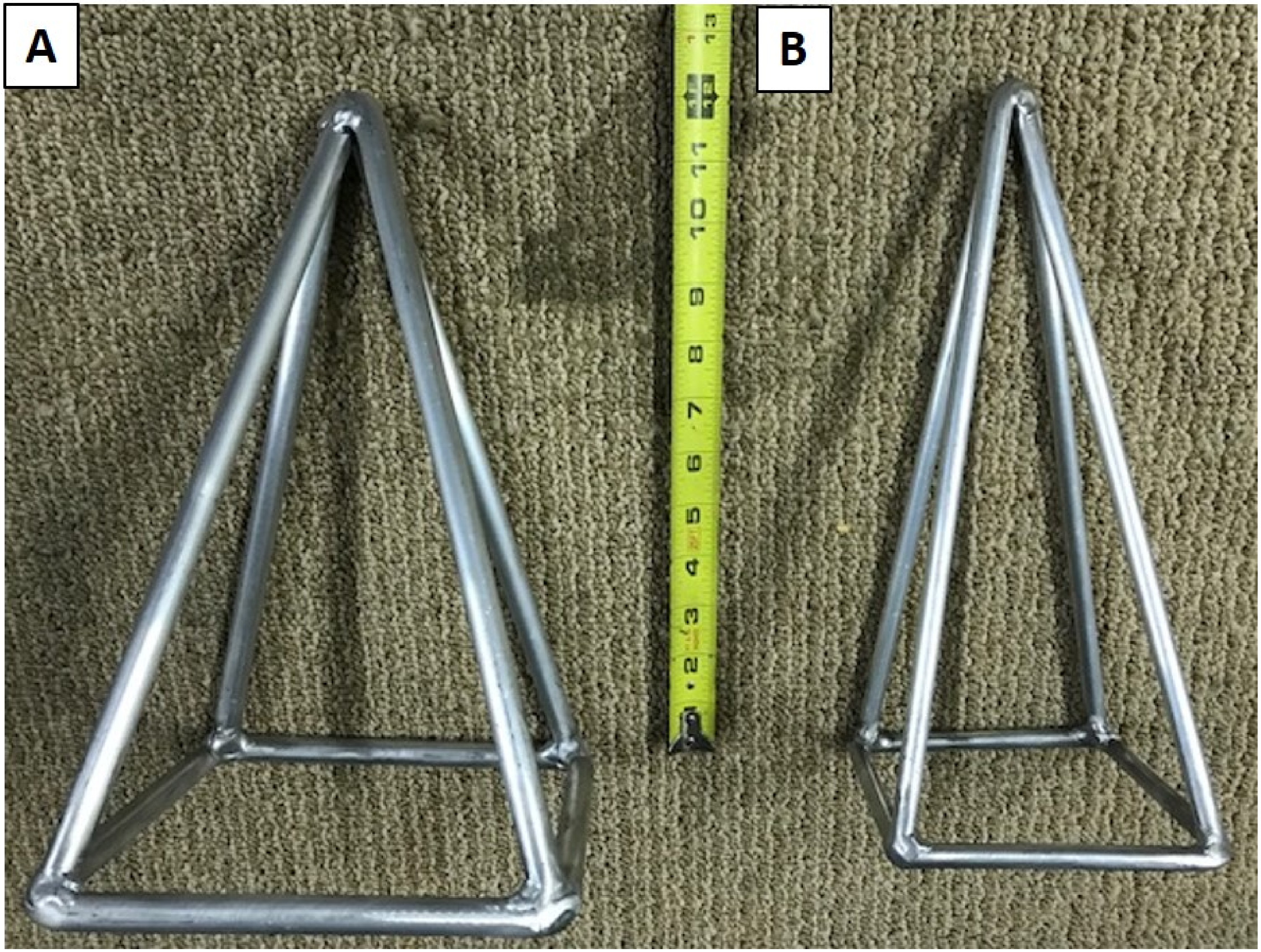

Figure 3. Federal fisheye BRD (A) compared to state fisheye BRD (B).

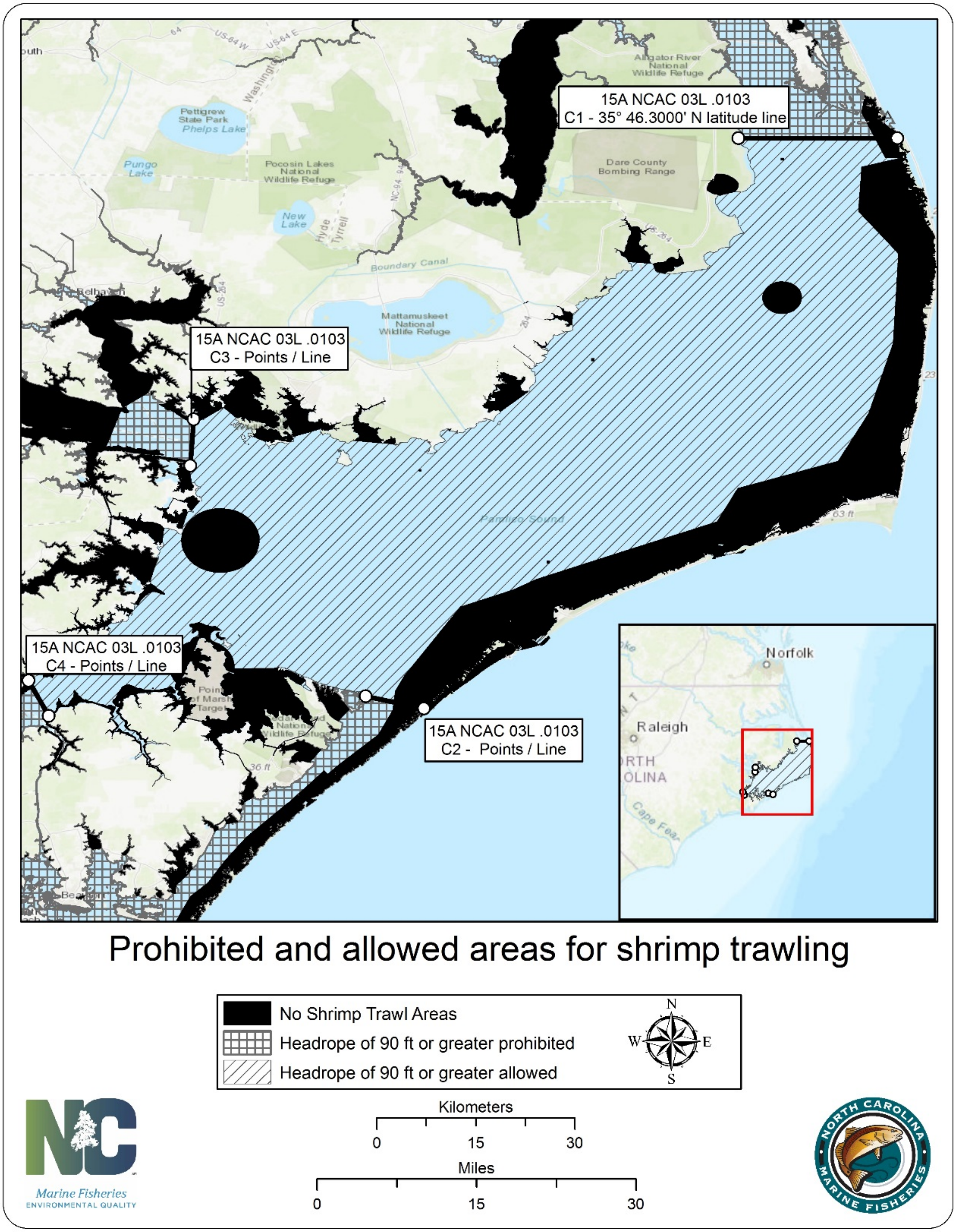

Figure **4. Location of area affected** (headrope of 90 ft or greater allowed) **by proposed recommendations from the Industry Workgroup.**

Appendix 1. MFC motions for Amendment 1 to the North Carolina Shrimp FMP to address bycatch.

In November 2013, prior to approving Amendment 1 for public comment the MFC passed a motion to:

Motion to add a recommendation to the draft Shrimp Fishery Management Plan Amendment 1 for a stakeholder group to initiate a three-year study testing minimum tail bag mesh T-90 (square mesh) panels, skylight panels, reduced bar spacing in turtle excluder devices and any other new methods of reducing unwanted finfish bycatch to achieve a minimum of a 40 percent reduction by weight compared to a control net with a Florida fish excluder, a federally approved turtle excluder device, and 1 1/2 inch mesh tail bag. The stakeholder group should partner with the Division of Marine Fisheries and N.C. Sea Grant to help secure funding for the study. If the target of a 40 percent reduction by weight in finfish is not achieved, further restrictions will be placed on the shrimp trawl industry to achieve the 40 percent reduction by weight. Those restrictions will be reviewed and discussed at that time.

Based on this motion management options examined in the FMP were separated into: 1) gear modifications, 2) effort management, 3) area restrictions, and 4) the use of other fishing gears. For each of these management options, issue papers were developed and presented to the Shrimp FMP Advisory Committee (AC), as well as the regional and standing advisory committees. Gear modifications evaluated included: tailbag mesh size, Turtle Excluder Devices (TEDs) with reduced bar spacing, T-90 tailbags, and Skylight Panels (Figure 1).

In February 2014, prior to the approval of the draft Shrimp FMP Amendment 1 for review by the Secretary of the Department of Environment and Natural Resources and the Joint Legislative Commission on Governmental Operations, the MFC passed a motion that became the final management strategy in Amendment 1 to address bycatch:

Motion to convene a stakeholder group to initiate industry testing of minimum tail bag mesh size, T-90 panels, skylight panels, and reduced bar spacing in turtle excluder devices to reduce bycatch to the extent practicable with a 40 percent target reduction. Upon securing funding, testing in the ocean and internal waters will consist of three years of data using test nets compared to a control net with a Florida Fish Eye, a federally-approved turtle excluder device and a 1.5-inch mesh tail bag. Results should minimize shrimp loss and maximize reduction of bycatch of finfish. Promising configurations will be brought back to the Marine Fisheries Commission for consideration for mandatory use. The stakeholder group may be partnered with the Division of Marine Fisheries and Sea Grant. Members should consist of fishermen, net/gear manufacturers and scientific/gear specialists.

The commission gave its final approval of the Shrimp Fishery Management Plan Amendment 1 and associated rules Feb. 19, 2015 and implementation of the rules came into effect May 1, 2015. Gear specific management strategies from Amendment 1 not only required the development of the stakeholder group and gear testing, but also required fishermen to use either a T-90/square mesh tailbag or other applications of square mesh panel (e.g., skylight panel), reduced bar spacing in a

TED, or another federal or state certified bycatch reduction device (BRD) in addition to existing TED and BRD requirements in all skimmer and otter trawls (Proclamation SH-2-2015; Figure 1).

Appendix 2. List of industry workgroup members, collaborators, and guest presenters.

Workgroup members:
Steve Parrish, net maker, Supply (passed, replaced by Douglas Todd)
Kenny Midget, net maker, Wanchese
Brent Fulcher, fish house owner/industry leader, New Bern
Clyde Potter, fishermen, Hobucken
Stevie Davis, fishermen, Sneads Ferry
Clyde Phillips, fishermen, Swansboro
Kenny Rustic, fishermen (skimmer), Gloucester
John Broome, fishermen, Wilmington
Virgil Potter, net maker, Bayboro
Douglas Todd, fishermen, Supply (replaced Steve Parrish)
Gordon Winfree, net maker, Shallotte
Mikey Daniels, industry leader/fish house owner (previously), fishermen, Wanchese
David Jarvis, fishermen, Bear Creek (added in 2018, tested gear in 2017)
Robbie Metcalf, fishermen, Carolina Beach (added in 2018, tested gear in 2017)

Collaborators:
Kevin Brown, NCDMF
Laura Lee, NCDMF
Blake Price, NOAA-HSU
Scott Baker, NC Sea Grant
Sara Miriabilio, NC Sea Grant

Guest Presenters:
Pingguo He, U-Mass Dartmouth
Frank Helies, GSAF
Dan Foster, NOAA-HSU
Gary Graham, Texas Sea Grant
Steve Eayrs, GMRI

Appendix 3. Comments from absentee workgroup members on proposed recommendations.

Robbie Metcalf verbal communication 4/18/18:

- Supported all of the recommendations, but has some concern with any shrimp loss over 5%.
- He supports continuing the workgroup and gear testing and improving the gear survey.
- He always wants to make things better for the industry and what's best for the fishery.

Clyde Phillips phone conversation 4/19/18:

- Supported a phase in period.

David Jarvis phone conversation 4/19/18:

- Does not want to go on record recommending a range of acceptable shrimp loss; if finfish bycatch reduction is significant, a larger range could be acceptable (beyond range used by workgroup of 3-5%).
- Comments: Supportive, even 10% is acceptable if finfish loss is significant.

- Does want to recommend continued collaborative bycatch reduction research, specifically continuance of the N.C. Shrimp Bycatch Reduction Industry Workgroup, requesting that funding from gear testing possibly come from surplus funds from increased license fees (i.e., Commercial Fishing Resources Fund). Industry continues to be willing to provide in-kind contributions.
- Comments: Fully supportive, willing to offer his vessel for continued testing.

- Does endorse for use on otter trawls fishing in inside waters (in areas where a combined head rope of 90-feet or greater is allowed as identified in the Shrimp FMP) the four combinations of bycatch reducing gears that met the target of 40% bycatch reduction, but specifically recommends:
- Comments: Supportive with some reservations because these gears haven't been tested on small boats. Doesn't believe it will be a burden on the industry.

- Use of the combination gear of double Federal fisheyes, 4-inch TED and 1 ¾-inch tailbag, again, in inside waters where an otter trawl with a combined head rope of 90-feet or greater is allowed. (Specific intent is not to have this change applied to other areas open to otter trawls, channel nets, and skimmer trawls until further bycatch reduction testing has been completed.)
- Comments: Supportive with some reservations because these gears haven't been tested on small boats. Doesn't believe it will be a burden on the industry.

- Recommends the N.C. Division of Marine Fisheries explores valid survey techniques to gather information on current bycatch reduction devices being used by industry.
- Comments: Supports as long as they are valid techniques.

14 Apr 18

To: Kevin Brown

RE: Industry Workgroup Draft Recommendation to the Marine Fisheries Commission

Kevin: The recommendations set forth in the Memorandum dated 6 Apr 2018 seem very logical proposals based on the testing results thus far.

O I totally agree that a range of acceptable shrimp loss should not arbitrarily be set. Any acceptable shrimp loss should be a function of the BRD's efficiency.

O I work in the ocean off New Hanover County and Brunswick County and I have very little knowledge of the working conditions in Pamlico Sound. After conducting research with a FRG through N.C. Sea Grant (2" reduced spaced TED vrs. 4" spaced TED), I have been using 2" reduced spaced TED's as BRD's. Because of different conditions, such as large quantities of moss, a reduced spaced TED might not be the best BRD for Pamlico Sound or other areas. Because of this, I would like to defer to the boat owners that this proposal would affect.

O The double Federal fisheye and 1 ¾ -inch tail bag produced the desired goal and should not be a burden for the boats affected.

John O Broome

John D. Broome

April 18, 2018.

Dear Marine Fisheries Commissioner,

My name is Kenny Rustick. I am a commercial fisherman from Carteret County, North Carolina and I serve on the Shrimp Industry Work Group. I was unable to attend the group's last meeting on April 4th, 2018 due to a prior surgery. I have been informed that several recommendations were voted on to pass onto the commission at it's May meeting.

I know one of the recommendations was for a 1 3/4" mesh tail bag. While the 1 3/4" mesh tail bag combined with other byrds showed a sizable reduction for the larger boats, it was never tested on the smaller boats like mine. I have tried this size tail bag before in the ocean on my boat and I noticed shrimp loss on 21/25 and 16/20 count shrimp. There were shrimp hanging out of the meshes on the tail bags when I would retrieve the trawls. I changed one tail bag to a 1 1/2" mesh and did not notice shrimp hanging out of the tail bag, and the 1 1/2" tail bag produced more shrimp.

Although this was by no means a scientific study, the 1 3/4" bags were a set of tail bags on a set of nets and turtle excluders I purchased. I tell you this because I believe we can reduce bycatch and do it with a minimal shrimp loss. I do believe we need more testing on the small boats. We could possibly try 1 5/8" and different byrd combinations. I have always found that what works for someone else might not work for me. So please give us some more time to find a combination of byrds that we know works for the small class boats.

Thank you for your time,

Kenny Rustick

Kenny Rustick

Brown, Kevin

From:	DOUGLAS TODD <dtodd@atmc.net>
Sent:	Thursday, April 19, 2018 2:02 PM
To:	Brown, Kevin
Subject:	[External] Bycatch

CAUTION: External email. Do not click links or open attachments unless verified. Send all suspicious email as an attachment to Report Spam.

Kevin the only comment that I have got back is some of the them want to know if the one fisheye with the 3-inch or less TED is still going to be approved to be used. The rest on the inform they were good with. Thanks Douglas Todd

Brown, Kevin

From:	stevie <steviedavis134@hotmail.com>
Sent:	Thursday, April 19, 2018 3:22 PM
To:	Brown, Kevin
Subject:	[External] Recommendations

CAUTION: External email. Do not click links or open attachments unless verified. Send all suspicious email as an attachment to Report Spam.<mailto:report.spam@nc.gov>

I , Stevie Davis, support each of the recommendations the workgroup is proposing to the Marine Fisheries Commission
Stevie Davis
04/18/2018

Sent from my iPhone

Brown, Kevin

From:	gordonsnet <gordonsnet@atmc.net>
Sent:	Thursday, April 19, 2018 5:52 PM
To:	Brown, Kevin
Subject:	[External] Industry Workgroup Draft Recommendation to the Marine Fisheries Commission

CAUTION: External email. Do not click links or open attachments unless verified. Send all suspicious email as an attachment to Report Spam.

I, Gordon Winfree, owner Gordons' Networks Inc. agree with the draft recommendations to the Marine Fisheries Commission listed in the memorandum.

Sent from Mail for Windows 10

INFORMATION WILL BE PROVIDED AT THE MEETING.

INFORMATION WILL BE PROVIDED AT THE MEETING.

May 17, 2018

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Anne Deaton and Casey Knight, Habitat and Enhancement Section

SUBJECT: Advisory Committee Recommendations on Region 4 Strategic Habitat Areas, Cape Fear River Basin

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As part of the Coastal Habitat Protection Plan (CHPP) implementation, Division of Marine Fisheries staff has been conducting regional spatial analyses of the coastal ecosystem to identify a subset of priority habitat complexes that are critical to fisheries species. These areas are referred to as Strategic Habitat Areas (SHAs) and were defined in the Marine Fisheries Commission's rulebook as "locations of individual fish habitats or systems of habitats that provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity" (15A NCAC 03I .0101(4)(h)).

At the November 2017 Marine Fisheries Commission meeting, staff presented draft Strategic Habitat Areas for Region 4, which includes the Cape Fear River system and estuarine waters from Surf City through Brunswick County. The analysis involves:

1. Using a GIS-based site-selection software to select the initial habitat areas based on their condition, value, and connectivity; and
2. Reviewing and modifying selections based on input from a scientific advisory committee.

The resulting SHA nominations encompassed 21.3 percent (74,451 acres) of the Region 4 focus area.

A presentation on the Region 4 Strategic Habitat Areas was given to the Southern and Habitat and Water Quality advisory committees, on April 11 and 12, respectively. No public comment was received. The advisory committee members had some questions and discussion, but did not propose any changes to the draft Strategic Habitat Area nominations. The Southern Advisory Committee unanimously approved a motion to recommend that the commission approve the draft Region 4 Strategic Habitat Areas. The Habitat and Water Quality Advisory Committee did not vote due to lack of a quorum, but recommended by consensus that the commission approve the draft Region 4 Strategic Habitat Areas.

Staff is asking the commission for final approval of the Region 4 Strategic Habitat Area report and nominated sites.

Strategic Habitat Area Nominations for Region 4:
The Cape Fear River Basin in North Carolina

DRAFT REPORT

October 2017

By

Casey Knight and Anne Deaton
North Carolina Division of Marine Fisheries
Wilmington, North Carolina

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REGIONAL ADVISORY COMMITTEE

Name	Affiliation
Troy Alphin	University of North Carolina - Wilmington
Nora Deamer	North Carolina Division of Water Resources, Basin Planning Section
Jeremy Humphrey	North Carolina Division of Marine Fisheries, Shellfish Sanitation Section
Jessie Jarvis	University of North Carolina - Wilmington
Mike Mallin	University of North Carolina - Wilmington
Robb Mairs	North Carolina Division of Water Resources, Water Quality Section
Kyle Rachels	North Carolina Wildlife Resources Commission
Fritz Rohde	National Marine Fisheries Service
Fred Scharf	University of North Carolina - Wilmington
Hope Sutton	North Carolina Division of Coastal Management, Coastal Reserve Program
Dawn York	Cape Fear River Partnership

GLOSSARY OF ACRONYMS

AFSA	Anadromous Fish Spawning Areas
CHPP	North Carolina Coastal Habitat Protection Plan
DCM	North Carolina Division of Coastal Management
DEQ	North Carolina Department of Environmental Quality
DMF	North Carolina Division of Marine Fisheries
DOT	North Carolina Department of Transportation
DWQ	North Carolina Division of Water Quality
DWR	North Carolina Division of Water Resources
GIS	Geographic Information System
HWQ	High Quality Waters
HU	Hydrologic unit
MFC	North Carolina Marine Fisheries Commission
NERR	National Estuarine Research Reserve
NHD	National Hydrologic Dataset
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRT	Natural resource targets
NWI	National Wetlands Inventory
ORW	Outstanding Resource Waters
PNA	Primary Nursery Area
SAV	Submerged Aquatic Vegetation
SGA	Shellfish Growing Area
SHA	Strategic Habitat Area
SSNA	Special Secondary Nursery Area
SS&RWQ	North Carolina Division of Marine Fisheries – Shellfish Sanitation and Recreational Water Quality section
TNPA	Trawl Net Prohibited Area
USACE	United States Army Corps of Engineers
WRC	North Carolina Wildlife Resources Commission

EXECUTIVE SUMMARY

Strategic Habitat Areas (SHAs) represent priority locations for protection or restoration due to their exceptional ecological functions or areas that are particularly at risk due to imminent threats to their ability to support coastal fisheries. Identification and designation of SHAs is a main goal of the North Carolina Coastal Habitat Protection Plan (CHPP). The identification of SHAs was conducted in a two-step process: 1) using GIS-based habitat and alteration data in a computerized site-selection analysis and 2) verifying and modifying information based on input from a scientific advisory committee. North Carolina Division of Marine Fisheries (DMF) staff and the advisory committee determined representation levels for multiple unique habitat types. There are also several types of alteration factors that are represented geospatially (i.e., hydrologic alterations, water quality degradation, and physical disturbances). The site selection program Marxan was used to select areas that met representation levels while limiting the selection of highly altered sites. The scientific advisory committee modified the computer results based on their expert knowledge and experience. The resulting SHA nominations encompass 21.3% of the Region 4 focus area (i.e., riparian targets within 500 m of the shoreline, open waters and the Atlantic Ocean out to 3 nmi) (Maps 7a-d). There were 43 discrete SHAs selected within Region 4. Large areas of Masonboro and Topsail sounds and the Cape Fear River were selected due to its biodiversity and high quality of habitats and fishery species. Many of the SHAs overlap with lands that are already managed for conservation. The SHAs were corroborated with biological data, ecological designations, and specific knowledge of the area. The SHA nominations will be incorporated into future conservation and restoration planning efforts.

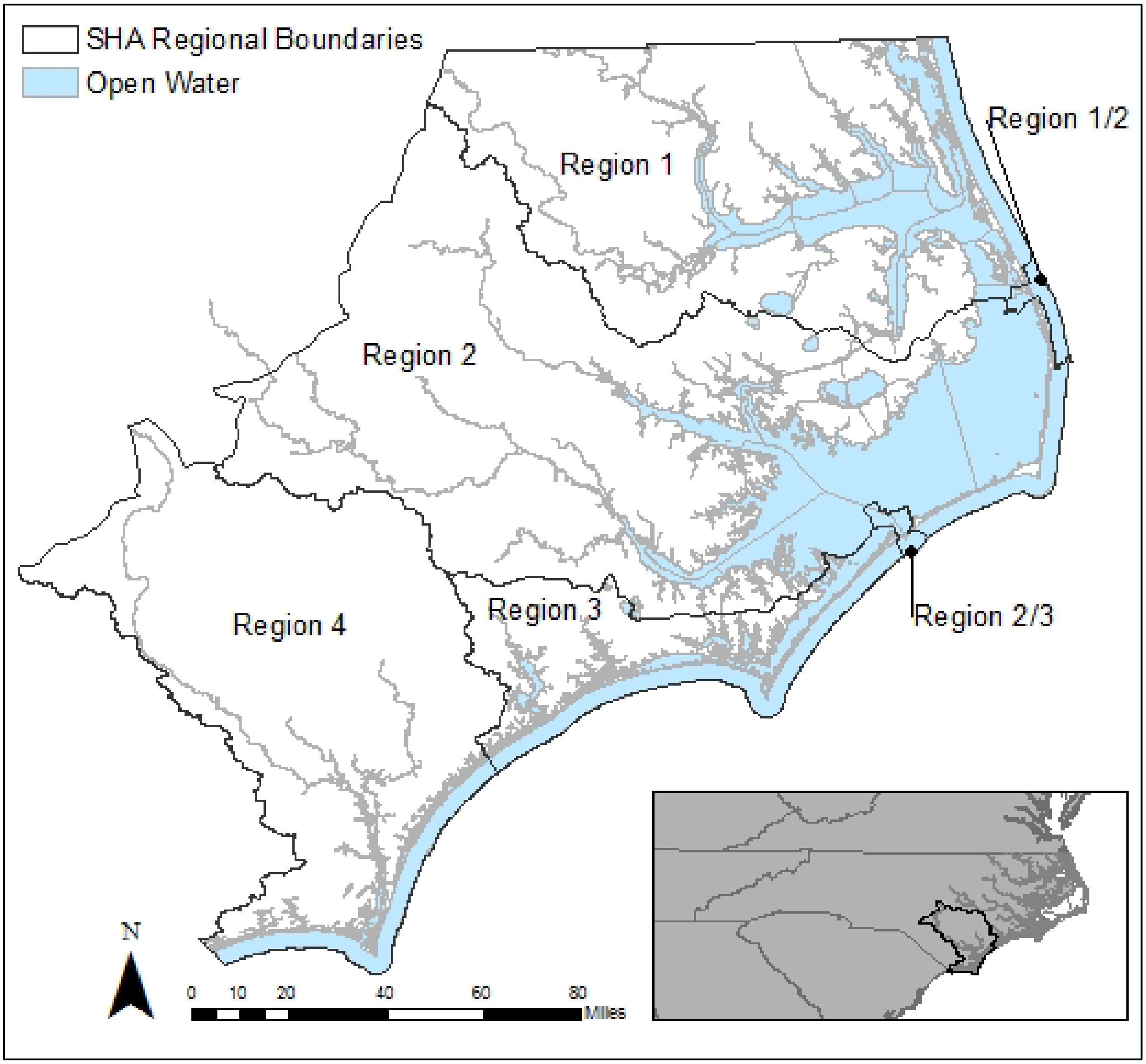
1 INTRODUCTION

The identification and designation of Strategic Habitat Areas (SHAs) for marine and coastal fishery species is a critical component in the implementation of North Carolina's approved Coastal Habitat Protection Plan (CHPP). Strategic Habitat Areas were defined in the CHPP as, "specific locations of individual fish habitat or systems of habitats that have been identified to provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity" (DEQ 2016; Deaton et al. 2010; Street et al. 2005). Criteria for identifying SHAs were developed by North Carolina Division of Marine Fisheries (DMF) staff and a Marine Fisheries Commission (MFC) advisory committee established in the summer of 2005. The committee developed a scientifically based process for identifying candidate areas for designation using biological data and the consensus of a regional expert panel (regional advisory committee). Their generic process is described in the guidance document entitled, "Process for Identification of Strategic Habitat Areas" (Deaton et al. 2006) that was approved by the MFC.

Strategic Habitat Area designations are based on regional analyses that identify optimally placed habitat areas of various ecological condition (exceptional or at risk). Strategic Habitat Areas may include areas that have already been protected by other designations, as well as areas not currently recognized in any way. Thus, areas designated as SHAs will require various site-specific management actions that best address the threats affecting that site. A network of designated SHAs providing habitat connections throughout North Carolina's coastal waters will help ensure that the complex life history needs of all species are met. Once SHAs are designated, resource managers may address priority fish habitat issues and take steps to prevent further alteration of strategic areas. Thus, the necessary protections for some areas may go above and beyond current measures designed to protect habitat. The nomination of SHAs will provide guidance for other conservation projects focused on conservation/acquisition, enhancement, or restoration projects.

The identification of SHAs addresses the continuing degradation and loss of important habitats referenced in the CHPPs (DEQ 2016; Deaton et al. 2010; Street et al. 2005). Current rules and policies of the resource management agencies fail to adequately address the individually small but cumulatively large alterations of fish habitat for development and associated human activities. Eventually, resource management and conservation agencies must address the issue of cumulative impacts in terms of fisheries ecosystem integrity and threshold alteration levels (DMF 2016; Deaton et al. 2010). On a regional scale, the concept of managing ecosystems to avoid cumulative impacts is partially addressed by assessing the condition of natural resource targets based on the presence, extent, and influence of multiple alteration factors. Maintaining a healthy ecosystem through focus on SHAs is based on the interdependent relationship between 1) natural resource targets, 2) alteration factors, 3) the spatial landscape, and 4) fish distribution and movement. Averting threshold levels of cumulative alteration to SHAs could be accomplished with both regulatory and non-regulatory tools, although the focus will be on non-regulatory tools.

Four regional analyses are being done to identify SHAs in coastal waters. Region 1 (Albemarle Sound System), Region 2 (Pamlico Sound system), and Region 3 (White Oak River Basin) were completed in 2009, 2011, and 2014 respectively (Map 1). SHAs in these regions are already being used by conservation groups to a limited extent. Sampling will begin in 2018 to verify fish productivity in SHAs and determine if modifications are needed. Once complete, staff will focus on developing site-specific measures to protect and enhance SHAs.



Map 1. Regional boundaries for Strategic Habitat Area (SHA) nominations.

1.1 Geographic Scope of Region 4

Region 4 is the southernmost region and has a riverine and estuarine component. It includes the southern estuaries from Surf City to the South Carolina border, and the Cape Fear River system upstream to approximately Lillington (Map 1). This upstream limit encompasses the historical anadromous fish spawning grounds of Smiley Falls (approximate fall line). Region 4 does not include the entire Cape Fear river basin, which extends to the Greensboro area. The Advisory Committee recognized that anadromous fish utilize waters upstream of the Region 4 boundary and that these areas are equally important but beyond the scope of this process. The estuarine component includes the coastal U.S. Geological Survey hydrologic units (HUs) east (part of the White Oak river basin) and west (part of the Lumber river basin) of the Cape Fear River basin. Hydrologic units are a defined area of land and water within a drainage divide. The USGS categorizes these with a standardized classification system, from the largest (region) to the smallest catchment basin (subwatershed). These coastal waters drain to the ocean through the numerous inlets.

The estuarine waters from Surf City through Sunset Beach include many mainland tidal creeks, small sounds, and inlets, as well as the Intracoastal Waterway. There are eight inlets in addition to the mouth of the Cape Fear, separating ten islands and the peninsula of Carolina Beach. These include New Topsail, Rich, Mason, Masonboro, Carolina Beach, Lockwood Folly, Shallotte, and Tubbs inlets. Mainland tidal creeks east of the Cape Fear in Pender, New Hanover, and Brunswick counties include Becky's, Virginia, Mallard, Topsail, Mill, Futch, Pages, Howe, Bradley, Hewletts, and Whiskey creeks. Tidal creeks west of the Cape Fear in Brunswick County include Dutchman Creek, Elizabeth, Lockwood Folly, Shallotte, and Calabash rivers occur (Map 2).

The riverine component of Region 4 includes the three lower subbasins of the Cape Fear River basin – Northeast Cape Fear, Black River, and Lower Cape Fear systems. Each subbasin includes other smaller waterbodies. Counties in riverine component of Region 4 include Brunswick, New Hanover, Pender, Duplin, Sampson, Bladen, and Cumberland, as well as a small amount of Hoke, Harnett, Wayne, and Onslow (Map 2).

Map 2. Major water bodies in Region 4.

All six habitat types described in the CHPP (DEQ 2016; Deaton et al. 2010; Street et al. 2005) are present within the region. The estuarine water column is characterized as having relatively small waterbodies a large portion of high salinity waters, and lunar tides with a large tidal range (3-5ft). Subsequently, shell bottom is primarily intertidal and salt marsh is extensive. Despite the small estuarine waterbodies in Region 4, there is a disproportionately large amount of shell bottom habitat, relative to other regions (DEQ 2016). Submerged Aquatic Vegetation (SAV) is less abundant and patchier than in the other regions but has been increasing over the past ten years. The Cape Fear system ranges from high salinity at the mouth, brackish in the vicinity of Wilmington, to non-tidally influenced fresh water in the upper portion of the region. The Cape Fear River is the only coastal river that drains directly to the ocean. Habitat is primarily forested wetlands, freshwater marsh, and riverine soft bottom. Most nearshore hard bottom in North Carolina predominantly occurs within Region 4. Concentrations of low to moderate profile hard bottom occur in state waters offshore of Topsail and Masonboro Islands (Onslow Bay) and Brunswick County (Long Bay). In federal waters, hard bottom is more extensive and is characterized as having greater topographic complexity.

Because of the large portion of shallow structured habitats in this region, designated Primary Nursery Areas are abundant in both the coastal and Cape Fear River components. Waters of the Cape Fear River, beginning downstream at Town Creek, and extending upstream through most of the region, are designated as Anadromous Fish Spawning Areas. A diversity of anadromous fish uses the Cape Fear, including striped bass, American shad, river herring, American eel, and Atlantic and shortnose sturgeon. In addition to supporting a diversity of aquatic habitat and fish, this region, referred to as the Cape Fear Arch, supports a unique geological landscape and high biodiversity in upland and wetland habitats and many endemic species (Cape Fear Arch Conservation Collaboration 2015).

1.2 Land Use

The counties of Brunswick, New Hanover, and Pender counties had the highest population increase in the 20 coastal counties between 1990 and 2015 (DEQ 2016). New Hanover and Brunswick counties are the first and third most populated counties. Most the increased population and associated development has occurred along the coast. Wilmington and Fayetteville are the two largest cities in the region. Development in, and urban sprawl adjacent to, these cities accounts for most of the increase in developed land use, and decrease in evergreen forest and forested wetlands. Land use is primarily residential along the coast and around Wilmington and Fayetteville. Land use in rural inland areas of Region 4 consists of crop and animal agriculture, as well as industrial use along the main stem of the Cape Fear River. Swine and poultry farms are highly concentrated in the Northeast Cape Fear watershed. Municipalities use the river for wastewater discharge and drinking water uptake. Many industries have been located along the Cape Fear River for decades due to the need to discharge industrial waste. Subsequently there are several EPA Superfund sites along the river. However, with these exceptions, many other areas between Wilmington and Fayetteville are fairly undeveloped and support productive habitat and fisheries.

The large population increase puts stress on the adjacent ecosystem. For example, of the coastal river basins, the Cape Fear, which includes the southern estuaries of Pender and New Hanover counties, had the second greatest acreage of impacted wetlands based on 401 permit records, from FY 2000- FY 2014. Increasing development stresses shell bottom habitat through point and nonpoint sources bringing sediment and other pollutants to shellfish waters. In 2014 48% of shellfish harvest waters in the southern counties (Onslow through Brunswick counties) were closed due to bacterial contamination. Despite multiple anthropogenic threats and large areas closed to harvest, 45% of the total landings in North Carolina came from the southern counties in 2013 (DEQ 2016), which further impacts the habitat. In the low salinity and fresh waters of the Cape Fear River, runoff from agriculture, concentrated animal feeding operations (CAFOs), and industrial discharges is the primary water quality threat. Since 2009, algal blooms of toxic *Microcystis* have been occurring in the Cape Fear River and been concentrated between Lock and Dam 1 and upstream of Lock and Dam 3. Obstructions to anadromous fish passage from dams are also a significant concern in the Cape Fear River.

There are several conservation lands that provide habitat protection as well as recreation opportunities. Among the conservation lands are two undeveloped islands (Masonboro Island National Estuarine Research Reserve and Lea Island), Fort Fisher State Recreation Area, Carolina Beach State Park, Holly Shelter and Angola Bay Game Lands, and Singletary Lake State Park and Raven Rock State Park. Additionally, over 24,000 acres have been purchased for conservation along the Black River, Northeast Cape Fear River, and Town Creek.

The DMF Management Review Team noted increasing shellfish harvest closures as a priority threat throughout the estuarine region. Degraded nursery conditions due to toxin and nutrient contamination, sedimentation, and altered flow and salinity was also considered a concern overall. Algal blooms, low dissolved oxygen, and stream obstructions to fish passage were the primary concerns in the Cape Fear system.

1.3 Identification of Priority Species

The priority fisheries species of the Cape Fear River Basin encompasses many shellfish and finfish including eastern oyster (*Crassostrea virginica*), clam (*Mercenaria mercenaria*), blue crab (*Callinectes sapidus*), shrimp (Penaeus spp.), bay scallop (*Argopecten irradians*), southern flounder (*Paralichthys lethostigma*), red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), kingfishes (*Menticirrhus* spp.), and spot (*Leiostomus xanthurus*). The Cape Fear River system is vital to anadromous species, including striped bass (*Morone saxatilis*), shad and river herring (*Alosa* spp.), and sturgeon (*Acipenser* spp.), that migrate up river for spawning; while the nearshore provides important habitat for gag (*Mycteroperca microlepis*), black sea bass (*Centropristis striata*), sheepshead (*Archosargus probatocephalus*), and mackerels (*Scomberomorus* spp.). Commercial and recreational landings support the value of these fisheries to the region. Commercially blue crab, shrimp, spot, oysters, king mackerel and gag grouper had the highest average landings (2005-2015) in Pender, New Hanover, and Brunswick counties (Table 1). Recreationally, flounder, red drum, spotted seatrout, king and Spanish mackerel, and spot were the most targeted species. These were all considered priority species for Region 4 by the DMF Management Review Team.

The CHPP states that “The areas that contribute most to the integrity of the system are a category of habitat termed Strategic Habitat Area” (DEQ 2016; Deaton et al. 2010). In a general sense, the abundance and diversity of habitat such as shallow nursery areas, SAV, and oyster beds is what sustains productivity in Region 4. The Region 4 SHA assessment focused on identifying habitat areas that provide critical functions to various life stages of priority species and are minimally degraded.

Table 1. Commercial landings of priority fishery species in Region 4 (DMF, unpublished data).

		Commercial Landings (lbs)			
	Species	2005	2010	2015	2005-2015 Avg.
Shellfish/ crustacean	Blue Crab	1,057,677	1,004,967	843,108	1,055,345
	Shrimp	680,384	806,235	588,632	585,211
	Oysters	87,933	159,419	153,741	149,931
	Clams	69,277	52,139	33,575	56,462
	Bay Scallop*	-	-	-	34
Estuarine finfish	Spot	261,357	57,982	119,858	165,403
	Kingfishes	99,450	133,107	118,682	102,408
	Southern Flounder	66,384	66,702	93,337	78,546
	Spotted Seatrout	8,921	9,224	15,156	12,464
	Red Drum	7,088	6,189	12,454	7,402
Anadromous fish	Striped Bass**	2,721	-	-	611
	Sturgeon	-	-	-	-
Reef Fish and coastal pelagics	Grouper, Gag	160,443	151,385	67,984	126,449
	Black Sea Bass	146,538	65,009	100,425	103,470
	Sheepshead	2,183	2,526	10,893	6,731
	King mackerel	266,007	158,996	128,748	210,080
	Spanish mackerel	2,183	2,526	10,893	6,731

*Landings in 2013 only
**Landings from 2005-2008 only

2 METHODOLOGY

A guidance document was developed to direct the methods for identifying SHAs (Deaton et al. 2006). The SHA identification process consists of three main phases, each of which requires input from a regional expert panel. The first phase in the SHA process is to identify priority species and habitats, and build a GIS database of existing biological and anthropogenic use data for Region 4. The DMF Management Review Team selected priority species for the region based on their importance to both the recreational and commercial fishing industries in the region. Once data was assembled by DMF staff, the regional advisory committee for Region 4 reviewed the data to ensure that they have sufficient spatial coverage and are current enough to be included in the SHA selection process. Then the committee examined the priority fish species for the region and suggested the amounts, or representation levels, of each habitat, or natural resource target (NRT), that should be included in the final SHA network. The second phase of the process was to run the site selection software Marxan (Ball et al. 2009) to determine an initial configuration of SHAs. Once the Marxan modeling was complete, the third phase consisted of an expert committee reviewing the Marxan selections and using corroborating information and their own ecological knowledge to modify the boundaries of the SHAs and derive a final network of SHA nominations.

2.1 Natural Resource Targets

In this analysis, natural resource targets (NRTs) are defined as the habitats that represent essential or unique components of the fisheries ecosystem. Natural resource targets vary by region and representation levels (the amount of a habitat to be included in the SHA nominations) should be chosen to differentiate between habitats that are used differently by fish species. To do this, priority species were grouped into shellfish/crustaceans, estuarine finfish, anadromous fish, and reef fish and coastal pelagics based on common life history strategies (Table 2). Each NRT was evaluated based on its value to these species' groups. Once identified, the use of NRT by each group of priority species was used to set representation levels. In addition to the importance to priority species, the ability of the NRT to improve water quality was also considered when setting representation levels. After an initial value was set, representation levels were adjusted by the advisory committee based on the regional importance of a habitat type, quality of habitat data, and overall amount of habitat in a region. Additional adjustments were made to the NRT representation levels by the advisory committee after reviewing the sensitivity analysis (See Sensitivity Analysis Section). A comprehensive list of NRTs and the chosen representation levels are listed in Table 2.

Table 2. Natural resource targets (NRTs) and representation levels used in the analysis and the importance of each NRT to priority species in Region 4.

Habitat type	Natural resource target	Total acres within focus area	Rep level (%)	Importance to priority species				
				Shellfish	Anadromous fish	Estuarine finfish	Reef fish & coastal pelagics	Water quality
				oysters, blue crabs, hard clams, bay scallops, shrimp	striped bass, American Shad, river herring, sturgeon	southern flounder, spot, spotted seatrout, red drum, weakfish	gag, black seabass, sheepshead, kingfishes, mackerels	-
Hard bottom	Hard Bottom	3,689	0				X	
SAV	High salinity SAV	653	60	X		X	X	X
Shell bottom	Intertidal shell bottom	3,708	60	X		X	X	X
	Subtidal shell bottom	2,395	60	X		X	X	X
SAV & shell bottom	SAV & shell bottom	130	80	X		X	X	X
Creeks & Rivers	Riverine soft bottom (0-3ft)	1,902	30	X		X		
	Riverine soft bottom (3-6ft)	292	20	X		X		
	Riverine soft bottom (>6ft)	1,174	20			X		
	Riverine soft bottom (ND)	6,764	10			X		
Shallow soft bottom	Palustrine soft bottom (0-3ft)	18	0			X		
	Palustrine soft bottom (ND)	195	0			X		
	Estuarine soft bottom (0-3ft)	18,430	20	X		X		
	Estuarine soft bottom (3-6ft)	3,507	20	X		X		
	Estuarine soft bottom (ND)	6,965	0	X		X		
	Marine soft bottom (0-3ft)	4,226	30			X	X	
	Marine soft bottom (3-6ft)	3,576	20			X	X	
	Marine soft bottom (ND)	54	0			X	X	
Deep soft bottom	Estuarine soft bottom (>6ft)	6,911	10	X		X	X	
	Marine soft bottom (>6ft)	176,471	0			X	X	
Wetland	Emergent wetland	34,629	10			X		X
	Forested wetland	58,637	30			X		X
	Shrub & scrub wetland	3,792	0					X
	Wetland edge	9,067	40			X		X
Low-elevation upland	Low-elevation upland	2,110	0					X
Water column	Streams (low elevation)	624	20			X		
TOTAL AREA		**349,918**						

2.1.1 Hard Bottom

Locations of hard bottom in the ocean are not well documented, and only a few datasets exist that give specific locations and information about hard bottom habitats. For the Region 4 analysis data was combined from several different data sets to create a mosaic of hard bottom habitat. The most extensive survey was based on the Southeast Area Monitoring and Assessment Program's reef-dependent fish collections from the 1990s (SEAMAP 2001). In addition, the list of wrecks and obstructions was obtained from the National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey Automated Wrecks and Obstructions Information System database (https://www.nauticalcharts.noaa.gov/hsd/wrecks_and_obstructions.html). Natural Heritage Areas of hard bottom outcrops near Fort Fisher, Masonboro, and Topsail were included (https://ncnhde.natureserve.org/content/data-download).

Due to geographic and spatial relationship constraints between NRTs (See Sensitivity Analysis section), the advisory committee decided to remove hard bottom from the model, setting a representation level of zero, and hand select during the corroboration stage (Table 2). Because of its importance to priority species such as gag, black sea bass, and sheepshead, as well as the lack of mapping data documenting hard bottom habitat, more than 77.4% of all known locations of hard bottom material were selected in the proposed SHA network for Region 4. Unlike previous regions DMF artificial reefs were not excluded from these selections since they are an important and large part of the offshore hard bottom habitat.

2.1.2 Submerged Aquatic Vegetation

Submerged aquatic vegetation beds were mapped using aerial photography interpretation and transect data interpolation. Source data for Region 4 were acquired in 2007 and 2015 (Benthic Habitat Mapping Program 1988-March 2016, unpublished data). Mapped SAV was further differentiated into low (0-15ppt) and high salinity (>15ppt) beds, based on NOAA salinity classifications. All SAV within Region 4 is classified as high salinity.

The presence of SAV indicates an area with good water quality that is sufficient to support a wide variety of essential ecological functions within coastal habitats, providing an implicit way to differentiate between qualities of areas in soft bottom habitats. In the context of other Marxan inputs, a sensitive habitat such as SAV can help distinguish between otherwise similar habitats such as shallow estuarine soft bottom. Because of its regional importance and uniqueness, high salinity SAV targets were set relatively high (60%; Table 2).

2.1.3 Shell Bottom

Shell bottom habitat in Region 4 was based on interpolated transect data collected by the DMF Estuarine Benthic Habitat Mapping Program (http://data.nconemap.com/geoportal/catalog/search/resource/details.page?uuid=%7BECC895DB-5A1C-4F13-98C3-1AB080F4B4B5%7D). The source data ranges from 1988 to 2016, depending on the geographic area. The shell bottom target is defined as areas with at least 30% coverage of shell material (typically oysters) in water generally less than 12 feet deep. Shell bottom is subdivided into intertidal and subtidal by the Estuarine Benthic Habitat Program.

Other sources of data were incorporated into the shell bottom target, including cultch planting sites (DMF unpublished data, 1981-2016) and an oyster reef mapping assessment of Masonboro Island conducted by the National Estuarine Research Reserve (NERR) (Manley 2016). Cultch planting data was classified as either intertidal or subtidal based on depth recorded at the time of deployment. All the Masonboro Island NERRs data was considered to be intertidal. Representation levels were set at 60% for both intertidal and subtidal shell bottom because they are regionally important as a fishery resource, serve as fish habitat, and are important for maintaining water quality (Table 2).

2.1.4 Submerged Aquatic Vegetation and Shell Bottom

The SAV and shell bottom data was derived from clipping the overlaid SAV and shell bottom layers. Areas where both occurred were then selected. Submerged Aquatic Vegetation and shell bottom are both indicators of good water quality and a high productivity. Therefore, the representation level for areas where both SAV and shell bottom occur was set very high at 80% (Table 2).

2.1.5 Low-Elevation Uplands

Low elevation uplands were included because they are potential sites for marsh migration as inundation occurs (DEQ 2016; Deaton et al. 2010). A 2008 3m digital elevation model with a vertical accuracy of 25cm was used to select areas less than two feet above mean sea level and having a patch size greater than $25m^2$. Non-wetland shorelines were also included in this category of uplands. The non-wetland shoreline was derived from the North Carolina Division of Coastal Management (DCM) estuarine shoreline data. A 15m landward buffer was applied to the shoreline and the resulting data was combined with the uplands derived from the digital elevation model. Only low elevation uplands adjacent to other NRTs were retained; all others were eliminated from the dataset. Due to this connectivity, the model will inherently select any upland associated with the other NRTs. Therefore, the representation level was set to 0% (Table 2).

2.1.6 Wetlands

Wetland targets were extracted from the U.S. Fish and Wildlife's National Wetlands Inventory (NWI) (https://www.fws.gov/wetlands/data/data-download.html) where wetlands are classified according to Cowardin et al. (1979). Wetlands of the following types are included in the Region 4 analysis: estuarine intertidal emergent, shrub/scrub, and forested wetlands and palustrine emergent, shrub/scrub, and forested wetlands. Only contiguous wetlands within 90m of a stream or shoreline of the National Hydrography Dataset (NHD) high resolution data (1:24,000-scale) were included as a target for assessment (https://nhd.usgs.gov/NHD_High_Resolution.html). Representation levels were set at 10%, 30%, and 0% for emergent, forested, and shrub/scrub wetlands, respectively, based on their importance to the estuarine system (Table 2).

2.1.6.1 Wetland Edge

This target consists of the linear wetland edge as designated in the DCM estuarine shoreline data layer with a 15m landward buffer applied. The wetland edge target does not differentiate between the marsh and forested edges. The inclusion of wetland edge, in addition to riparian/interior wetlands, was intended to capture the important linear ecotone within aquatic systems. Wetland shorelines are important habitat for juveniles of some priority species and the Wetland edge representation level was set relatively high at 40% to reflect such (Table 2).

In Region 2, the linear wetland edge features were buffered and converted to polygon features while in the Region 3 analysis the wetland edge feature was kept linear. In Region 3, the linear features were retained with the intention of maintaining the integrity of the linear dataset and avoiding potential false inflation of alterations many of the alterations affecting these features were also linear. For Region 4, most alteration are polygon features and it was determined that buffering the wetland edge would not falsely inflate alteration factors.

2.1.7 Streams

Small creeks and streams were represented using the NHD high resolution data (1:24,000-scale). This dataset represents a connected network of stream channels. The streams were clipped out of the open water features to leave a continuum from linear to polygon water features. The artificial connectors, an artifact needed to maintain the datasets continuous linear network between features, were removed from the dataset because they did not represent stream habitat. A representation level of 20% was set for streams (Table 2).

2.1.8 Soft Bottom

Soft bottom or water column habitat was designated as any area without submerged aquatic vegetation, shell bottom, or other structured habitat. This soft bottom habitat was derived using the DCM estuarine shoreline layer, the NOAA bathymetry contour dataset (https://data.noaa.gov/dataset/bathymetric-contours), and the NWI dataset. The DCM estuarine shoreline data was used as the base or boundary for the soft bottom natural resource target because it was recently digitized using high quality aerial imagery. All other structured features were removed from this base layer; this includes submerged aquatic vegetation, shell bottom, and hard bottom. The remaining features were considered soft bottom features.

The soft bottom features were further classified by depth and system. The depth categories included 0-3ft, 3-6ft, and no depth (ND). These distinctions are important because they correspond to major differences in ecological function (i.e., shallow water nurseries). Depth was derived from the NOAA bathymetric dataset. The no depth category was assigned to channel-like hydrographic features adjoining more open waters, or where the bathymetric charts indicated no data.

The soft bottom habitats are also classified into system type using the NWI wetland polygon dataset and classification system (Cowardin et al. 1979). Any soft bottom habitat that did not have a hydrological connection to riverine or estuarine systems by linear water features was removed from the dataset by applying a 30m buffer to determine connectedness of water bodies (i.e., lakes and ponds) to adjacent water features. Soft bottom habitats are classified into riverine, estuarine, palustrine, and marine systems.

- Riverine systems were separated from low salinity estuarine systems based on a linear or meandering morphology and a substantial (non-ditched) drainage network upstream.
- Palustrine systems included all non-tidal wetlands dominated by trees, shrubs, persistent emergent, and all such tidal wetlands were ocean-derived salinities are below 0.5ppt. Palustrine systems were only included if they were directly adjacent to connected lacustrine, riverine, or estuarine systems.

- Estuarine systems included all open waters and intertidal flats between riverine and marine systems. The estuarine system also includes pond-like features surrounded by estuarine wetlands.
- Marine systems included the subtidal and intertidal waters of the coastal ocean and inlets.

Due to the abundance of soft bottom in the region most representation levels were set below 30% (Table 2).

2.1.9 Rare or Listed Species

Rare or listed species are not included in the Marxan analysis as targets, but are taken into account indirectly through targeting of associated habitats, and during the second phase of the analysis using expert modification. Rare, listed, or species of special concern in this region include Atlantic sturgeon (*Acipenser oxyrhynchus*), bottlenose dolphins (*Tursiops truncatus*), diamond back terrapins (*Malaclemys terrapin*), and sea turtles (Chelonioidea). Sturgeon habitat will be indirectly targeted through selection of riverine wetlands, streams, and soft and hard bottom. Green (*Chelonia mydas*), Kemp's ridley (*Lepidochelys kempii*) and loggerhead sea turtles (*Caretta caretta*) are the most common of the five listed sea turtle species in Region 4. They tend to enter the estuarine waters in the spring as they migrate north for the summer, and leave the estuary in the fall to migrate south for winter. Sea turtles are highly mobile, moving around as they feed opportunistically. Within Region 4, sea turtles are can be found throughout the sounds and lower rivers. Their habitat will be targeted indirectly through deep soft bottom.

2.2 Alteration Factors

Alteration factors are human activities that impact the marine environment. The alteration factors used in the analysis are listed in Table 3 and described in the sections below. Each factor was evaluated for duplication or overlap with other factors.

Table 3. Alteration factor weightings used in the Marxan analysis. Scale: 0-3, with 0 being no impact, and 3 being the most severe impact.

	Water based Alterations (impact hydrology)*								Land based Alterations (impact water quality)								Physical	
Habitat Categories	Culvert-obstructions	Impoundments	Bridge Constrictions	Bulkheads	Rip rap	Dredged channels	Ditched/Drained	Canals and boat basins	Major NPDES**	Minor NPDES**	Marinas	Animal operations**	Developed land use***	Agricultural land use***	Prohibited shellfish harvest	Docks and piers	Trawling and dredging allowed	Mechanical clam harvest
Hard bottom	1	1	0	1	1	2	0	2	2	1	1	0	1	1	2	1	3	3
Creeks & rivers	2	3	2	1	1	1	1	1	2	1	2	3	2	2	1	0	1	1
SAV	1	1	1	2	1	3	0	3	2	1	2	2	3	2	1	2	3	3
Shell bottom	1	0	1	0	0	3	0	1	1	1	2	1	2	1	1	0	2	3
SAV & shell bottom	1	1	1	2	1	3	0	2	2	1	2	2	3	2	1	2	3	3
Deep soft bottom	0	1	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1	1
Shallow soft bottom	0	1	0	2	1	2	0	1	1	1	2	2	1	1	1	0	2	1
Upland	1	1	0	2	1	0	0	1	0	0	0	0	1	1	0	0	0	0
Wetland	1	2	1	1	0	2	3	1	1	1	1	1	1	1	0	1	0	0
Streams	2	2	2	1	1	1	2	0	3	2	0	3	3	2	0	0	0	0
Wetland edge	1	2	1	3	2	2	2	2	1	1	1	1	1	1	0	1	0	0

*Based on existing GIS layers and factored as presence/absence
**Calculated as the # of a facility per HU
***National Pollutant Discharge Elimination System – Relativized proportion of development/agricultural land use per HU

2.2.1 Natural Resource Targets and Alteration Factors

The NRTs for Region 4 were grouped into general habitat categories for the purpose of applying alteration factor ratings. For example, wetland types are affected similarly by ditching and drainage; therefore, they form one habitat type for alteration calculations. However, there were linear and polygon wetland and shoreline features. To apply the equations to calculate the total alteration score presented in Appendix A, the linear features were converted into narrow polygon features. Like Regions 2 and 3, this conversion was also done for linear water features including linear stream features. The NRT groupings are listed in Table 3 and described below:

- Hard Bottom – All categories of hard bottom.
- Creeks/rivers – Polygon water column features for riverine hard and soft bottom NRTs. This category represents soft bottom under flowing water conditions.
- SAV – All categories of SAV, only high salinity present in Region 4.
- Shell bottom – All categories of shell bottom.
- Soft bottom, deep – All categories of estuarine and marine soft bottom >6ft deep. This category represents soft bottom under standing water conditions.
- Soft bottom, shallow – All categories of estuarine and marine soft bottom <6ft deep. This category represents soft bottom under standing water conditions.
- Uplands – Line features that were converted to polygons using a buffer 15m landward from non-wetland shorelines. The polygon target for low-elevation uplands was included in this basic habitat type for alteration.
- Wetland – Wetland edge was converted to polygons using a buffer 15m landward from wetland shorelines. Interior wetlands are polygon features >15m from wetland edge.
- Streams – Linear water column features converted to polygons using a 2m buffer. The size was based on the thinnest polygon water features, usually upper end of creeks or rivers.

Many other factors were considered, but were not included for various reasons. Among them were 2014 DWQ use support ratings, stormwater outfalls, surface water intakes, silviculture operations, and beach nourishment. Some of these may have been used during the corroboration phase. Their use was excluded for the following reasons:

- DWQ use support ratings were not used because we primarily needed aquatic life use support, which wasn't available in all locations.
- Stormwater outfall maps from DWQ and SS&RWQ were incomplete for the region and overlap with the Shellfish Growing Areas was observed.
- The GIS data for water intakes was extremely outdated, excludes certain areas and intakes under large minimum thresholds, and the National Pollutant Discharge Elimination System (NPDES) sites covered major surface water intakes.
- Silviculture/forestry discharge not included because literature review in the CHPP indicated minor effect on habitat and water quality, previous advisory committees felt the alterations to aquatic habitat were minor relative to other threats, and the activity was difficult to represent spatially (Deaton et al. 2010; Uphoff 2008).
- Dredge material disposal on beaches has occurred in the region (Deaton et al. 2010), but was not included in the alteration factors, since it was episodic and less frequent than

beaches with long term storm protection projects.

Alteration factors are loosely categorized as affecting hydrology (water based alterations), water quality (land based alterations), or physical structure of habitat (physical). The effect of alteration factors on natural resource targets is represented in various ways:

1. *Overlap of habitat area and alteration footprint* – This was done for alteration features whose effect could be accurately represented by a discrete area. Altered areas for these features were represented as the area of the intersection between the habitats present and alteration. This was done for culverts-obstructed areas, impoundments, bridge constrictions, bulkheads, rip rap, dredged channels, ditched/drained wetlands, canals and boat basins, prohibited shellfish harvest, marinas, piers and docks, trawling, and mechanical clam harvest.

2. *Relative impact of the alteration factor to a hydrologic unit* – This was done for alteration factors that were theorized to have watershed-level impacts or if the data collection prevented a discrete area of impact from being delineated. To calculate this, the extent of an alteration factor (whether it be total area or the sum of point counts) is summed across HUs and amount is scaled to the maximum value occurring in any HU in the region. This includes major and minor NPDES, animal operations, developed land use, and agricultural land use.

2.2.2 Hydrological Alterations

2.2.2.1 Culvert-Obstructed Areas

This factor identifies the stream segments with possible obstructions by small barriers including culverts and fords. The source of the culvert data was the North Carolina Barrier Prioritization tool which was funded by American Rivers and supported by the Southeastern Aquatic Resource Partnership (SARP). This tool uses state specific natural heritage and anadromous fish data to prioritize dams for fish passage within the state boundaries (Hoenke 2014). The Small Barriers layer from the prioritization tool was used to identify culvert obstructed areas.

2.2.2.2 Impoundments

Impounded waters include the watershed upstream from documented dam locations and waterfowl impoundments. The data sources for dam locations were the North Carolina Barrier Prioritization tool which was funded by American Rivers and supported by the SARP. This tool uses state specific natural heritage and anadromous fish data to prioritize dams for fish passage within the state boundaries (Hoenke 2014). The Dam Inventory Version 2 layer from the prioritization tool was used to identify dam obstructed areas.

2.2.2.3 Bridge Constrictions

The bridge constriction data set was selected from the North Carolina Division of Transportation structure location shapefile (https://connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx). From this shapefile, all bridges, including railways and ferry ramps, were extracted.

2.2.2.4 Bulkheads and Riprap

Shoreline type was extracted from the DCM 2012 estuarine shoreline data (McVerry 2012).

Alteration was rated as the ratio of the linear distance of stabilized structures to the linear distance of shoreline within an assessment hexagon. Stabilized structures were defined as bulkheads and riprap. Alteration weight was higher for bulkheads than for riprap because bulkheads have a greater negative impact on the shorelines than riprap.

The DCM survey was based on 2006-2010 county level digital orthophotos from 6 in and 2ft resolution. Structure polyline features were generated from the imagery through heads up digitizing, and were digitized at a scale between 1:300 and 1:500 feet. Structure type is based on the presence of commercial, recreational, and erosion control structures and attributed using guidance provided in a DCM-generated methodology entitled "Charting the Estuarine Environment: A methodology spatially delineating a contiguous, estuarine shoreline of North Carolina" (Geis and Bendell 2008).

2.2.2.5 Dredged Channels

This alteration factor includes areas dredged by the U.S. Army Corp of Engineers (USACE) on a regular basis. The source data originated from 2003. This layer does not include channels dredged by the DWR or private channels dredged for deep-water access, though these areas may be included in the canals and boat basins layer.

2.2.2.6 Ditched/Drained

For the drained alteration factor, wetland polygons with partially drained wetland areas were derived using the “drained” attribute in the NWI dataset. For the ditched alteration factor, linear stream features with the classification in the high resolution NHD was used to select all ditched stream linear features.

2.2.2.7 Canals and Boat Basins

This alteration factor included very long and straight polygon features (obvious canals for navigation) or relatively short and straight elongate polygons with no upstream hydrology (short, water access canals or boat basins). Some of the delineated boat basins could also overlap with marinas. This file was created by clipping out portions of the DMF jurisdictional waters that appeared to be excavated canals or boat basins. Some modifications were made by hand to remove areas that were for obviously for drainage instead of navigation when compared with 2012 imagery data. Additional areas were added based on obvious canals and boat basins observed through various aerial imagery sources.

2.2.3 Water Quality and Land Use Alterations

2.2.3.1 Major and Minor NPDES

The major and minor NPDES alteration factor was derived from NPDES sites locations provided by DWR (2014 data). Major NPDES sites in the region included municipal wastewater discharges such as those for the cities of Carolina Beach, Wilmington, Elizabethtown, Fayetteville, and Dunn, and the counties of Brunswick and Harnett, and industrial process and commercial wastewater discharges such as those for the Brunswick and Sutton power plants, Riegelwood papermill, and other manufacturers. Minor NPDES sites were more numerous and variable in type including water plants and water conditioning, municipal, industrial process and commercial, groundwater remediation. It is difficult to determine the area of influence for a point source without a detailed hydrologic model. Therefore, major and minor NPDES sites were summarized by HU to approximate the measure of alteration. The number of major and minor NPDES within HUs was then scaled by the maximum number occurring in the region, and the relative amount was used to calculate the relative severity of alteration. Major NPDES were given high alteration scores than minor NPDES to account for the scale of impact.

2.2.3.2 Marinas

Wildlife Resources Commission and DMF Shellfish Sanitation data on marina locations and numbers of slips were combined to make one dataset of all facilities with > 10 slips. The DMF Shellfish Sanitation Section has determined the area of influence for marinas or groups of marinas on a creek that subject to buffer rules for shellfish sanitation reasons. Areas within these buffers are closed to shellfish harvest. These closure areas were used to define the area of impact for marinas in this analysis. The total number of slips at marina facilities were aggregated by closure area and divided by the amount of area in the closed area to get a slips/acre metric. This metric was scaled to the maximum value occurring in Region 4.

2.2.3.3 Animal Operations

Locations and size of animal operations were obtained for poultry, swine, and cattle operations. The swine and cattle operation information was compiled by the Environmental Working Group (EWG) and Waterkeeper Alliance from the Department of Environmental Quality's (DEQ) animal operations permits as of January 2015 (DWR, Animal Feeding Operations Unit) and the 2015 USDA Cropland data layer. The poultry data was compiled by EWG and Waterkeeper Alliance from the Poultry - Inventory and Sales USDA AG Census 2007 and 2012 and the 2015 USDA Cropland data layer. It is difficult to determine the area of influence for a point source without a detailed hydrologic model. Therefore, animal operations were summarized by HU to approximate the measure of alteration. The number of animal operations within each HU was then scaled by the maximum number occurring in the region, and the relative amount was used to calculate the relative severity of alteration.

2.2.3.4 Developed Land Use

This alteration factor was derived from the NOAA 2006-2010 C-CAP Southeast Region Land Cover dataset using the open space, low-, medium-, and high-intensity development classifications (https://coast.noaa.gov/digitalcoast/tools/lca). The total area of developed land-use within each HU was calculated and scaled to the maximum proportion of developed land use found within a HU in the study region. A greater proportion of developed land within a HU suggests greater nutrient and chemical loadings from non-point development sources.

2.2.3.5 Agricultural Land Use

This alteration factor was derived from the NOAA 2006-2010 C-CAP Southeast Region Land Cover dataset using the cultivated crops and pasture/hay classifications. The total area of agricultural land-use within each HU was calculated and scaled to the maximum proportion of developed land use found within a HU in the study region. A greater proportion of agricultural land within a HU suggests high nutrient and chemical loadings from non-point agricultural sources.

2.2.3.6 Prohibited Shellfish Harvest

Prohibited shellfish harvest area information was obtained from DMF's Shellfish Sanitation and

Recreational Water Quality section. Areas prohibited to shellfish harvest due to high pathogenic microbe counts or automatic closures around wastewater treatment outfalls and marinas were included to represent non-point source alterations at spatial scales smaller than hydrologic units. The benefit of representing localized impacts was considered more important than minimizing the redundancy of similar alterations (i.e., NPDES, marinas, and developed land-use). In addition, the prohibited areas are documented alterations and not reliant upon inferred data. Only waters that fall under the categories of prohibited and conditionally approved, closed harvest are included; conditionally approved, open harvesting waters were not included because they are considered restorable by DMF. Areas that are closed due to marina buffer rules were removed from this layer to avoid duplication with the marina alteration layer.

2.2.3.7 Piers and Docks

Shoreline structures were obtained from the DCM 2012 estuarine shoreline structures survey data (McVerry 2012). These areas were considered an impact due to shading open water areas, disturbing the adjacent shoreline, and increased activity in the surrounding areas.

2.2.4 Physical Disturbance

2.2.4.1 Trawling

Trawling area information was obtained from DMF's Fisheries Management section. This GIS layer depicts areas that are open to both permanently and temporarily open to trawling. Both permanently and temporarily open areas were given the same alteration score because data on trawling effort and frequency of opening in specific areas and is not available at this time.

2.2.4.2 Mechanical Clam Harvest Areas

Mechanical Clam Harvest Area information was obtained from DMF's Fisheries Management section. Two types of mechanical harvest gear are currently used in North Carolina: the hydraulic escalator dredge and the clam trawl or "clam kicking" vessel. The hydraulic escalator dredge penetrates the bottom to a depth of about four inches and collects clams as they are forced from the bottom by water pressure and conveyed up the escalator aboard the vessel. In clam trawling or "kicking", clams are dislodged from the bottom with prop wash, and a heavily chained trawl with a cage behind the boat collects the clams (DMF 2017). It is accepted that these mechanical harvest methods can negatively impact submerged aquatic vegetation (SAV) and oyster rocks (Peterson et al. 1987), thus, mechanical harvest of clams is allowed only in certain areas. In addition, some of these areas are open and closed on a rotational basis of either one or two years (Table 4).

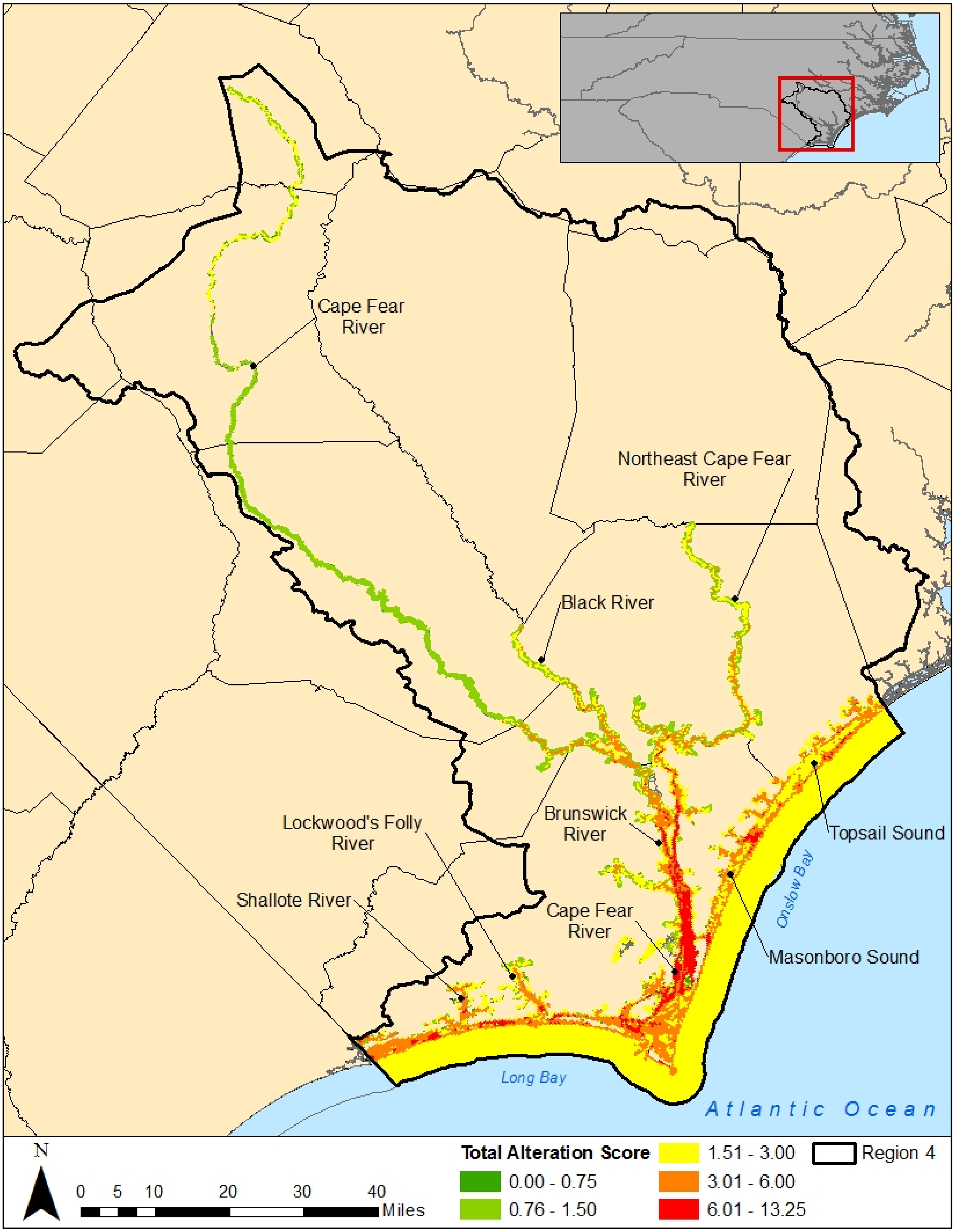
Table 4. Daily mechanical hard clam harvest limits by water body (DMF 2017).

Waterbody	Daily harvest limit (number of clams)	Additional information
Northern Core Sound	5,000	Rotates one year open and one year closed opposite the open/close rotation of the New River
Southern Core Sound	5,000	Limit reduced from 6,250 in 2001. Open annually.
North River	3,750	Open annually
Newport River	3,750	Open annually
Bogue Sound	3,750	Open annually
White Oak River	6,250	Rotates one year open and one year closed opposite the open/close rotation of the New River
New River	6,250	Rotates one year open and one year closed opposite the open/close rotation of the White Oak River and the ICW in the Onlsow/Pender
New River Inlet	6,250	Open annually from Marker 72A to the New River Inlet
ICW Onslow/Pender counties area	6,250	Intracoastal Waterway (maintained marked channel only) from Marker #65, south of Sallier's Bay, to Marker #49 at Morris Landing. All public bottoms within and 100 feet on either side of the Intracoastal Waterway from Marker #49 at Morris Landing to the "BC" Marker at Banks Channel. Open every other year when the New River is closed.

2.2.5 Total Alteration/Cumulative Impacts

Each alteration factor was assigned a rating ranging from 0 (no impact) to 3 (high impact) for each habitat type it coincides with (Table 3). Habitat types were condensed to match the major CHPP habitat types. The factor ratings were guided by a modified version of a similar table in the CHPP (Street et al. 2005), which is based on literature reviews and expert opinion. Because multiple factors can contribute to the alteration within a region, we combined the alteration factors into a total alteration rating which quantitatively measure the amount of alteration to each hexagon in the region. Briefly, the alteration score weights the alteration severity by the amount of habitat impacted and combines the severity and impact scores into a total score by weighting the proportion of each habitat present in the hexagon. The alteration score for Region 4 was created using a combination of ArcGIS models and R scripts and is described in detail in Appendix A.

The Cape Fear and Black rivers above the Pender county line, the Northeast Cape Fear River above Burgaw, and from the north of Wrightsville Beach to Topsail sound were the least altered. The most altered areas were in near developed areas such as the city of Wilmington, Sunny Point Military Terminal, Ocean Isle Beach, and Wrightsville Beach and other industrial areas long the Cape Fear River main stem (Map 3).



Map 3. Total alteration scores for Region 4. Higher values equate to greater degradation.

2.3 Marxan Analysis

The site selection software Marxan (Ball and Possingham 2000) was used to identify an initial network of areas to be considered for SHA nomination. The use of Marxan was recommended by Smith (2005) and adopted as SHA methodology. The site-selection tool makes it possible to systematically consider multiple NRTs and various socio-economic factors represented as alterations. The program provides a way to select a network of areas (classified by hexagon units) with the least amount of alteration, which is helpful because specific information is not available on maximum tolerable alteration levels and specific minimum habitat sizes needed to maintain functional ecosystems (Stewart et al. 2003). Often, the results of site selection tools are used as a starting point from which to determine boundaries and are not considered a final output (Geselbracht et al. 2009). Final SHA nominations incorporate expert scientific knowledge to consider additional biological information and socio-economic factors that may not have been included in the Marxan inputs.

The selection algorithm considers several sources of data and uses an iterative approach to consider multiple network configurations until it finds one that minimizes the area and cost of the network. Marxan allows the user to input data on the distribution of conservation features (NRTs in the SHA process) and to define the desired amount of each conservation feature desired in the final reserve configuration (representation level in the SHA process). In addition, Marxan allows the user to input a cost for each planning unit, which can vary based on the process objectives. The SHA process uses the alteration score of a hexagon as the cost under the assumption that alteration is equal to habitat degradation. This framework was designed so that Marxan would select a network of habitat areas that have the least amount of habitat degradation. In addition to the habitat and alteration inputs, Marxan allows the user to input a boundary length modifier (BLM), which controls the length of border allowed by the solution. Raising the BLM increases the cost of spatially disparate solutions, forcing the program to select hexagons that are closer together.

A Marxan analysis consists of a series of runs, each of which represents a solution found by the computer program. A grid of hexagons is laid over GIS habitat and alteration layers. The hexagons in this analysis were 30 acres in area, 432 m in diameter, and 216 m in side length. Each run consists of a specified number of iterations. Each iteration considers a new reserve configuration of hexagons by calculating a cost that is based on the success of the program at meeting its targets, the reserve boundary length and the cost of the area considered. Iterations proceed until the change between iterations is minimal or the maximum number of iterations is reached. The number of runs, iterations, and BLM can all be specified in the Marxan settings and should be adjusted to attain an appropriate solution for each analysis.

2.3.1 Sensitivity Analysis

A sensitivity analysis was conducted for Region 4, similar to those conducted for other regions, to determine the optimal scenario (DMF 2014; DMF 2011). By examining the scores of the best solution, the distribution of the scores that resulted from an analysis with 500 runs and 100,000 iterations was more robust among lower score, indicating that Marxan is finding similar solution across runs. The BLM was adjusted to 0.005 to produce the most efficient solution in terms of cost (minimizing the total alteration score) and area selected between runs. Lower BLM values produced solutions that were smaller, spatially isolated clusters with less than three hexagons.

Higher BLM values produced SHAs that were too large for management and consumed too much area.

As recommended by the advisory committee, an additional sensitivity analysis was conducted to examine the representation levels of the NRTs to determine which, if any, NRT make the largest difference in the solution generated by the model. That is, in some cases particular targets may have little impact on solutions while other targets are largely driving the solution. Therefore, when the most influential targets that are driving the model are set to zero the total area and alteration score or cost of the model will decrease (Ardron et al. 2010). Most NRTs generated small differences in total cost and total alteration score when set to zero. Forested wetlands, hard bottom, and wetland edge were determined to be the NRTs with the most influence on the model (Figure 1).

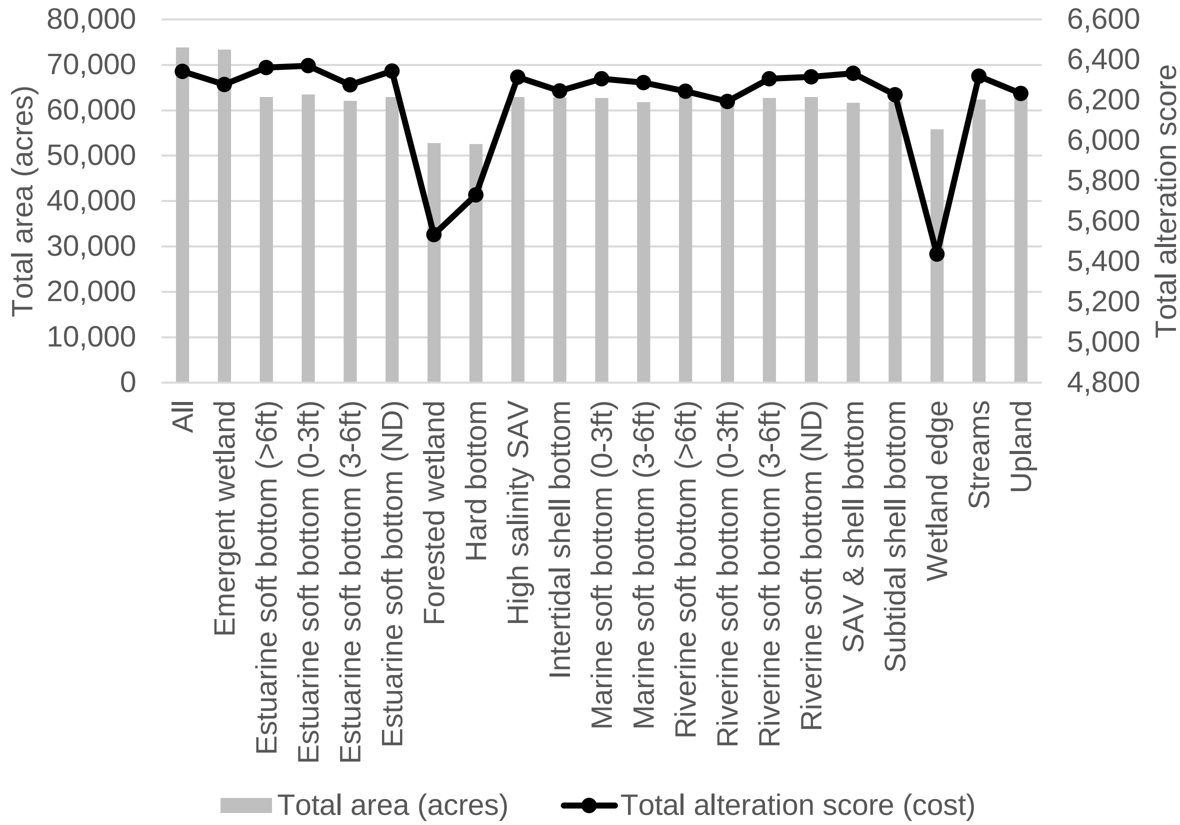


Figure 1. Natural resource target (NRT) sensitivity analysis examining the effect of excluding NRTs from the model on total area (acres) and total alteration score.

After discussing the results of the NRT sensitivity analysis and the resulting Marxan solutions, the advisory committee felt the targets influence on the model was due to geographic distribution and the spatial relationship between these NRTs. To account for this, forested wetlands and wetland edge representation levels were decreased to 30% and 40%, respectively. Hard bottom was excluded setting the representation level to 0% to keep the model from selecting large areas of the ocean with marine soft bottom. The advisory committee felt that the only areas of the ocean that should be included as a SHA would be known hard bottom locations and areas near inlets. Thus, these areas were added in during the corroboration phase.

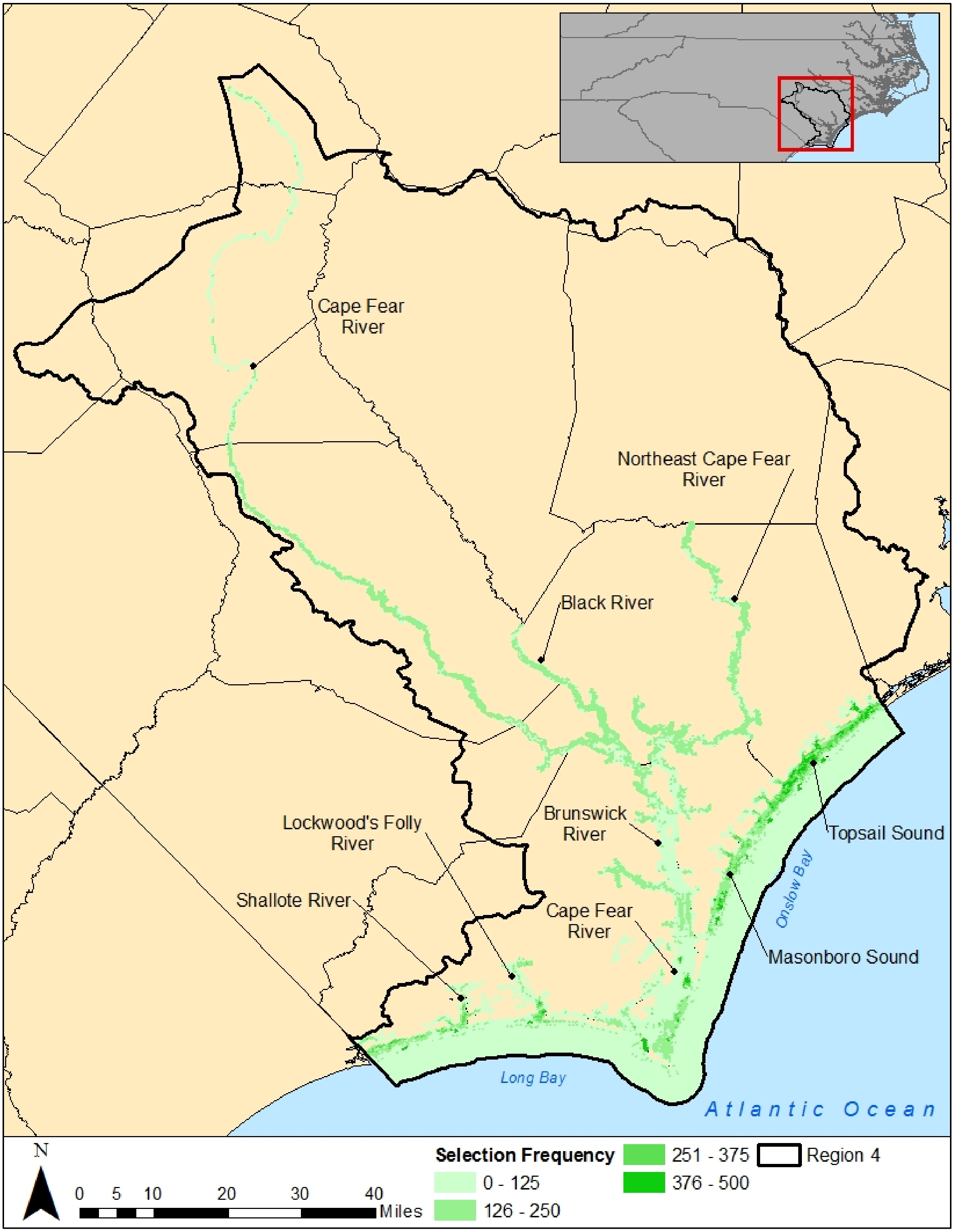
Once preliminary areas were identified by the Marxan solution, SHA selections were modified and refined by the advisory committee of regional experts using other known sources of quantitative or qualitative ecological or fishery information and professional knowledge (referred to as corroborating data). Public input is required to finalize identification and nomination of areas for eventual SHA designation.

3 MARXAN RESULTS

After the natural resource targets and total alteration layer were assembled, Marxan was run at the specified representation levels for the NRTs representing priority fisheries habitats (Table 2). Map 4 depicts the Marxan selections from the best solution with the most efficient BLM. This resulted in a large number of small SHAs that the advisory committee thought would be difficult to manage. Thus, the advisory committee decided to examine the selection frequencies, since high selection frequencies are an indication that an area was not erroneously chosen (Map 5). During the corroboration phase, the committee kept the high selection frequency areas in mind.

Large areas of Masonboro and Topsail sounds and associated tidal creeks were selected by Marxan and are known to be ecologically important for both fish and shellfish in Region 4. Other sizeable areas that were selected included parts of Shallotte and Lockwoods Folly rivers and Bald Head Island. Very little was selected around the city of Wilmington due to high alteration scores. The Cape Fear, Black, and Northeast Cape Fear rivers and their tributaries had some clustering but were less connected most likely due to the width of the focus area (Maps 4 and 5).

Map 4. Marxan best solution for Region 4.



Map 5. Marxan selection frequency for Region 4.

4 CORROBORATION

The advisory committee reviewed the initial Marxan selections and made expert modifications as needed. The SHA committee grouped individually selected hexagons into manageable polygons for the corroboration and identification process. Modifications to the Marxan selected SHAs were made using an overlay of selected hexagon polygons on digital imagery. The SHA committee examined maps of both the selection frequency and alteration ratings for guidance during the manual selection phase. For each polygon or group of contiguous hexagons selected by Marxan, the SHA committee reviewed data included within each polygon cluster to confirm inclusion/exclusion as a SHA in a consistent and data based manner. This included examination of the alteration scores, selection frequencies, amount and type of targets present, habitat diversity and rarity, supporting biological data, existing ecological designations that were not included as NRTs (i.e., Anadromous Fish Spawning Areas, Significant Natural Heritage Areas, and water quality ratings) and connectivity with adjacent selections and protected areas. Known studies or information from committee members regarding habitat condition and fish utilization of specific areas were also included.

Criteria to base modifications on included:

- Habitats present – rare, vulnerable, diverse
- Occurrence of ecological designations
- Alteration factors, ratings, and other known alterations not included in the model
- Selection frequency
- Fish and shellfish data/information available from DMF sampling or other research
- Water quality impairment status (5 categories)
- Regional importance of a functional area
- Size/isolation/connectivity/shape

The designations and biological data used in this phase of the analysis are listed in Table 5. These data are meant to support computer-selected areas and identify important areas omitted by the Marxan analysis. Examples of omitted areas would be a tidal creek that was rated as altered but still supports fish or shellfish production that consistently produces high catches relative to other areas. Ideally, the regional expert panel would have local qualitative knowledge that further supported the area as having high fishery or habitat value. Areas with existing habitat designations that were not selected by Marxan could also indicate areas that should be considered for manual addition to the list of proposed SHAs.

Table 5. Ecological designations and biological data used for corroboration of Strategic Habitat Areas (SHAs) in Region 4.

Type	Description	Source
Ecological designations	Anadromous Fish Spawning Areas	MFC designation
	Blue crab spawning sanctuaries	MFC designation
	Estuarine Primary Nursery Areas (PNAs)	MFC designation
	Permanent Secondary Nursery Areas (PSNAs)	MFC designation
	Special Secondary Nursery Areas (SSNA)	MFC designation
	Trawl Net Prohibited Areas (TNPA)	MFC designation
	Inland PNAs	WRC designation
	Open shellfish harvesting waters	DMF - SGA classification
	Significant Natural Heritage Areas (aquatic and terrestrial)	Natural Heritage Program designation
	Lands managed for conservation	DEQ One NC Naturally
Species/ productivity data	Use support and biotic indices for fish and invertebrates (freshwater streams only) – index values	DWR
	Fish and shellfish data	DMF programs 120, 915, 510 and WRC data

The committee used the criteria listed above to cut, extend, and/or consolidate Marxan clusters within the focus area. Selected hexagons with fewer than three contiguous hexagons were excluded. Consolidations were based on avoiding what the group considered over-represented habitats (e.g., soft bottom >6ft) and connecting similar contiguous areas or under-represented habitats. The advisory committee also expanded polygons into some unselected areas that were known to be highly productive for priority species or habitats. The visual assessment was conducted systematically around the region, starting from the South Carolina line and working north to Topsail Sound and then up the Cape Fear River. Inlet areas were added in by default because of their importance to migratory fishes moving in and out of those areas.

4.1 Post-Corroboration Results

Following the corroboration phase, there were a total of 43 discrete areas selected for nomination totaling 74,451 of the 349,918 acres of focus area. This comprises 21.3% the total focus area. All targets were met except for marine soft bottom 0-3ft and 3-6ft, and riverine soft bottom 0-3ft, 3-6ft, and >6ft. However, both marine and riverine soft bottom with no depth exceeded target by 70% and 30%, respectively. The advisory committee felt the exceeded targets of soft bottom unknown depths accounted for the lack of meeting targets in the other depth categories (Table 6). The acreage of NRTs within each individual SHA is included in Table 7. The habitat targets that were most exceeded were soft bottom (riverine, estuarine, and marine, no depth), emergent wetlands, wetland edge, and low elevation uplands. Following ground truthing, developed portions of low elevation uplands should be omitted.

Maps 7a-d and 8a-d show the selection frequency and alteration scores of the post-corroboration

SHA nominations. Most of the areas that were not initially selected by Marxan, but were added by the advisory committee for connectivity reasons, had low selection frequency but low to medium alteration scores.

Table 6. Representation levels, target area (acres), and resulting amounts of natural resource targets (NRTs) post-corroboration.

Habitat type	Natural resource target	Focus area (acres)	Rep. level (%)	Target area (acres)	Percent of target (%)
Hard bottom	Hard Bottom	3,689	0	2,856	77.4
SAV	High salinity SAV	653	60	521	79.8
Shell bottom	Intertidal shell bottom	3,708	60	2,517	67.9
	Subtidal shell bottom	2,395	60	1,570	65.5
SAV & shell bottom	SAV & shell bottom	130	80	113	86.8
Creeks & Rivers	Riverine soft bottom (0-3ft)	1,902	30	386	20.3
	Riverine soft bottom (3-6ft)	292	20	43	14.8
	Riverine soft bottom (>6ft)	1,174	20	103	8.8
	Riverine soft bottom (ND)	6,764	10	2,660	39.3
Shallow soft bottom	Palustrine soft bottom (0-3ft)	18	0	0	0.0
	Palustrine soft bottom (ND)	195	0	13	6.6
	Estuarine soft bottom (0-3ft)	18,430	20	5,768	31.3
	Estuarine soft bottom (3-6ft)	3,507	20	701	20.0
	Estuarine soft bottom (ND)	6,965	0	4,243	60.9
	Marine soft bottom (0-3ft)	4,226	30	846	20.0
	Marine soft bottom (3-6ft)	3,576	20	432	12.1
	Marine soft bottom (ND)	54	0	38	71.1
Deep soft bottom	Estuarine soft bottom (>6ft)	6,911	10	699	10.1
	Marine soft bottom (>6ft)	176,471	0	4,953	2.8
Wetland	Emergent wetland	34,629	10	15,733	45.4
	Forested wetland	58,637	30	23,136	39.5
	Shrub & scrub wetland	3,792	0	916	24.2
	Wetland edge	9,067	40	5,507	60.7
Low-elevation upland	Low-elevation upland	2,110	0	470	22.3
Water column	Streams (low elevation)	624	20	226	36.2
TOTAL AREA		349,918		74,451	21.3

Table 7. Amount of each natural resource target (NRTs) in acres present in each Strategic Habitat Area (SHA) nomination.

		Strategic Habitat Area ID										
Habitat Type	Natural Resource Target	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Hard bottom	Hard bottom	0	1	0	0	0	582	105	0	0	0	0
SAV	High salinity SAV	0	0	0	1	0	0	0	1	0	0	258
Shell bottom	Intertidal shell bottom	155	141	2	196	0	0	0	45	0	0	0
	Subtidal shell bottom	142	74	0	127	0	0	0	1	0	0	0
SAV & shell bottom	SAV & shell bottom	0	1	0	4	0	0	0	0	0	0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	0	0	8	0	0	0	0	0	0
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	227	314	18	467	0	0	0	201	18	0	1,681
	Estuarine soft bottom (3-6ft)	15	11	4	2	0	0	0	20	118	0	176
	Estuarine soft bottom (ND)	96	51	4	63	0	0	0	32	0	0	662
	Marine soft bottom (0-3ft)	73	107	0	61	0	0	0	0	76	218	17
	Marine soft bottom (3-6ft)	7	0	0	39	0	0	0	0	67	213	7
	Marine soft bottom (ND)	0	14	0	0	0	0	0	0	0	0	0
Deep soft bottom	Estuarine soft bottom (>6ft)	18	26	5	16	0	0	0	9	172	0	13
	Marine soft bottom (>6ft)	12	0	0	17	0	193	187	0	97	2,618	10
Wetland	Emergent wetland	1,521	378	72	465	0	0	0	718	0	0	3,339
	Forested wetland	1	0	0	5	289	0	0	0	0	0	41
	Shrub & scrub wetland	59	5	0	2	0	0	0	1	0	0	57
Wetland shoreline	Wetland edge	230	99	6	94	25	0	0	103	0	0	541
Low-elevation upland	Low-elevation upland	16	27	0	25	1	0	0	4	2	1	54
Water column	Streams (low elevation)	7	1	0	2	6	0	0	4	0	0	7
Total Area		2,579	1,253	111	1,586	329	775	292	1,139	550	3,050	6,863

Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID										
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Hard bottom	Hard bottom	39	0	0	46	72	383	0	65	1,203	0	2
SAV	High salinity SAV	0	0	0	0	0	0	37	0	0	3	221
Shell bottom	Intertidal shell bottom	0	0	4	0	0	0	413	0	0	291	1,269
	Subtidal shell bottom	0	0	479	0	0	0	211	0	0	34	501
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	14	0	0	1	93
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	191	0	0	0	610	0	0	337	1,671
	Estuarine soft bottom (3-6ft)	0	0	0	0	0	0	109	0	0	23	170
	Estuarine soft bottom (ND)	0	0	4	0	0	0	1,237	0	0	335	1,575
	Marine soft bottom (0-3ft)	0	0	0	21	0	0	46	0	0	2	224
	Marine soft bottom (3-6ft)	0	0	0	19	0	0	1	0	0	2	78
	Marine soft bottom (ND)	0	0	0	0	0	0	4	0	0	3	17
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	0	0	150	0	0	23	112
	Marine soft bottom (>6ft)	156	98	0	208	91	234	0	32	492	13	71
Wetland	Emergent wetland	0	0	66	0	0	0	2,004	0	0	911	3,849
	Forested wetland	0	0	0	0	0	0	55	0	0	12	70
	Shrub & scrub wetland	0	0	1	0	0	0	47	0	0	21	58
Wetland shoreline	Wetland edge	0	0	10	0	0	0	652	0	0	397	1,676
Low-elevation upland	Low-elevation upland	0	0	0	11	0	0	74	0	0	31	52
Water column	Streams (low elevation)	0	0	0	0	0	0	4	0	0	2	2
Total Area		195	98	755	305	163	617	5,668	97	1,695	2,441	11,711

Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID										
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Hard bottom	Hard bottom	39	0	0	46	72	383	0	65	1,203	0	2
SAV	High salinity SAV	0	0	0	0	0	0	37	0	0	3	221
Shell bottom	Intertidal shell bottom	0	0	4	0	0	0	413	0	0	291	1,269
	Subtidal shell bottom	0	0	479	0	0	0	211	0	0	34	501
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	14	0	0	1	93
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	191	0	0	0	610	0	0	337	1,671
	Estuarine soft bottom (3-6ft)	0	0	0	0	0	0	109	0	0	23	170
	Estuarine soft bottom (ND)	0	0	4	0	0	0	1,237	0	0	335	1,575
	Marine soft bottom (0-3ft)	0	0	0	21	0	0	46	0	0	2	224
	Marine soft bottom (3-6ft)	0	0	0	19	0	0	1	0	0	2	78
	Marine soft bottom (ND)	0	0	0	0	0	0	4	0	0	3	17
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	0	0	150	0	0	23	112
	Marine soft bottom (>6ft)	156	98	0	208	91	234	0	32	492	13	71
Wetland	Emergent wetland	0	0	66	0	0	0	2,004	0	0	911	3,849
	Forested wetland	0	0	0	0	0	0	55	0	0	12	70
	Shrub & scrub wetland	0	0	1	0	0	0	47	0	0	21	58
Wetland shoreline	Wetland edge	0	0	10	0	0	0	652	0	0	397	1,676
Low-elevation upland	Low-elevation upland	0	0	0	11	0	0	74	0	0	31	52
Water column	Streams (low elevation)	0	0	0	0	0	0	4	0	0	2	2
Total Area		195	98	755	305	163	617	5,668	97	1,695	2,441	11,711

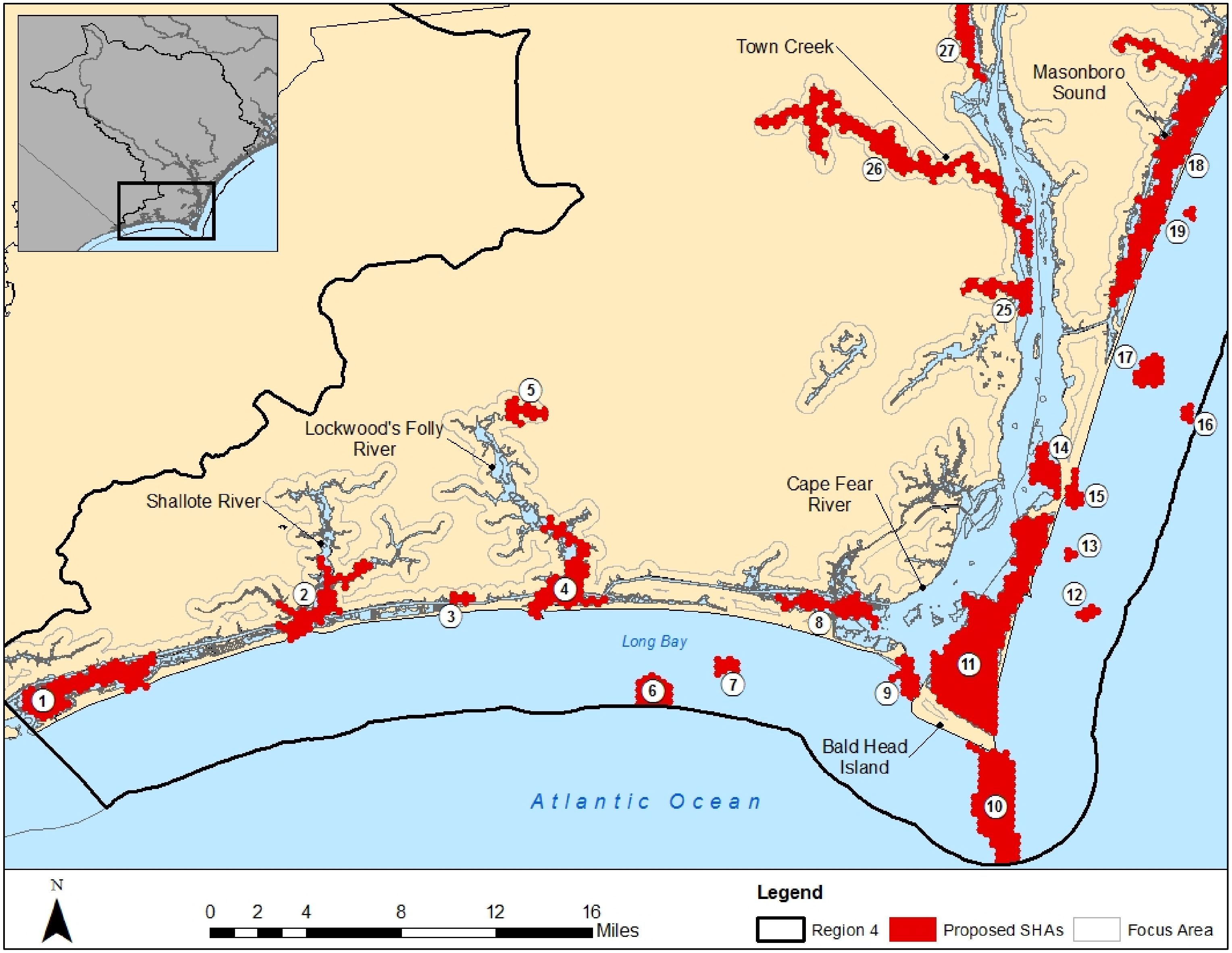
Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID										
		23	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Hard bottom	Hard bottom	105	250	0	0	0	0	0	0	0	0	0
SAV	High salinity SAV	0	0	0	0	0	0	0	0	0	0	0
Shell bottom	Intertidal shell bottom	0	0	0	0	0	0	0	0	0	0	0
	Subtidal shell bottom	0	0	0	0	0	0	0	0	0	0	0
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	0	0	0	0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	121	265	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	14	29	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	30	73	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	23	207	1	15	40	58	274	69	372
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	0	3	30	0	0	0	0	0	0
	Estuarine soft bottom (3-6ft)	0	0	0	0	51	0	0	0	0	0	0
	Estuarine soft bottom (ND)	0	0	0	50	115	18	0	0	0	0	0
	Marine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	154	0	0	0	0	0	0
	Marine soft bottom (>6ft)	0	302	0	0	0	0	0	0	0	0	0
Wetland	Emergent wetland	122	0	330	753	648	377	2	9	19	0	186
	Forested wetland	0	0	65	1,469	19	8	276	581	2,422	341	1,627
	Shrub & scrub wetland	0	0	74	268	32	0	11	0	5	0	19
Wetland shoreline	Wetland edge	0	0	56	268	63	63	29	27	168	27	129
Low-elevation upland	Low-elevation upland	0	0	2	27	9	3	0	1	2	0	6
Water column	Streams (low elevation)	0	0	6	39	2	4	5	2	14	2	6
Total Area		227	552	721	3,451	1,124	488	363	678	2,904	439	2,345

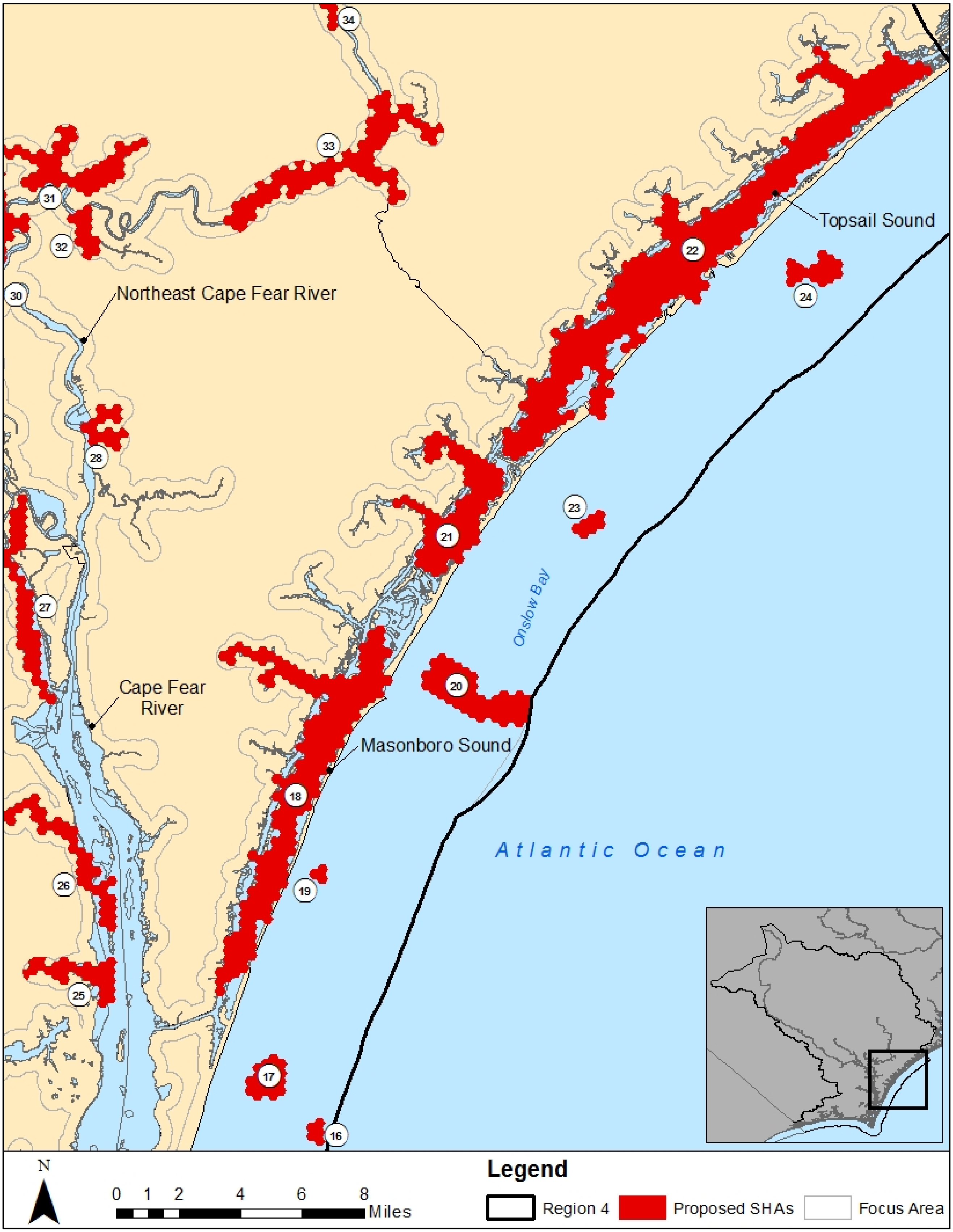
Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID									
		34	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
Hard bottom	Hard bottom	0	0	0	0	0	0	0	0	0	0
SAV	High salinity SAV	0	0	0	0	0	0	0	0	0	0
Shell bottom	Intertidal shell bottom	0	0	0	0	0	0	0	0	0	0
	Subtidal shell bottom	0	0	0	0	0	0	0	0	0	0
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	0	0	0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	234	68	88	36	173	0	20	0	0	519
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	455	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	13	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0
Wetland	Emergent wetland	0	0	13	0	0	11	7	17	36	3
	Forested wetland	1,340	787	515	493	2,026	3,853	2,621	2,206	1,533	472
	Shrub & scrub wetland	1	2	0	0	0	0	25	132	104	0
Wetland shoreline	Wetland edge	147	88	57	59	119	370	0	0	0	0
Low-elevation upland	Low-elevation upland	16	4	53	11	2	37	0	0	0	0
Water column	Streams (low elevation)	2	11	13	9	6	43	7	6	6	8
Total Area		1,740	960	739	608	2,326	4,782	2,680	2,361	1,679	1,002

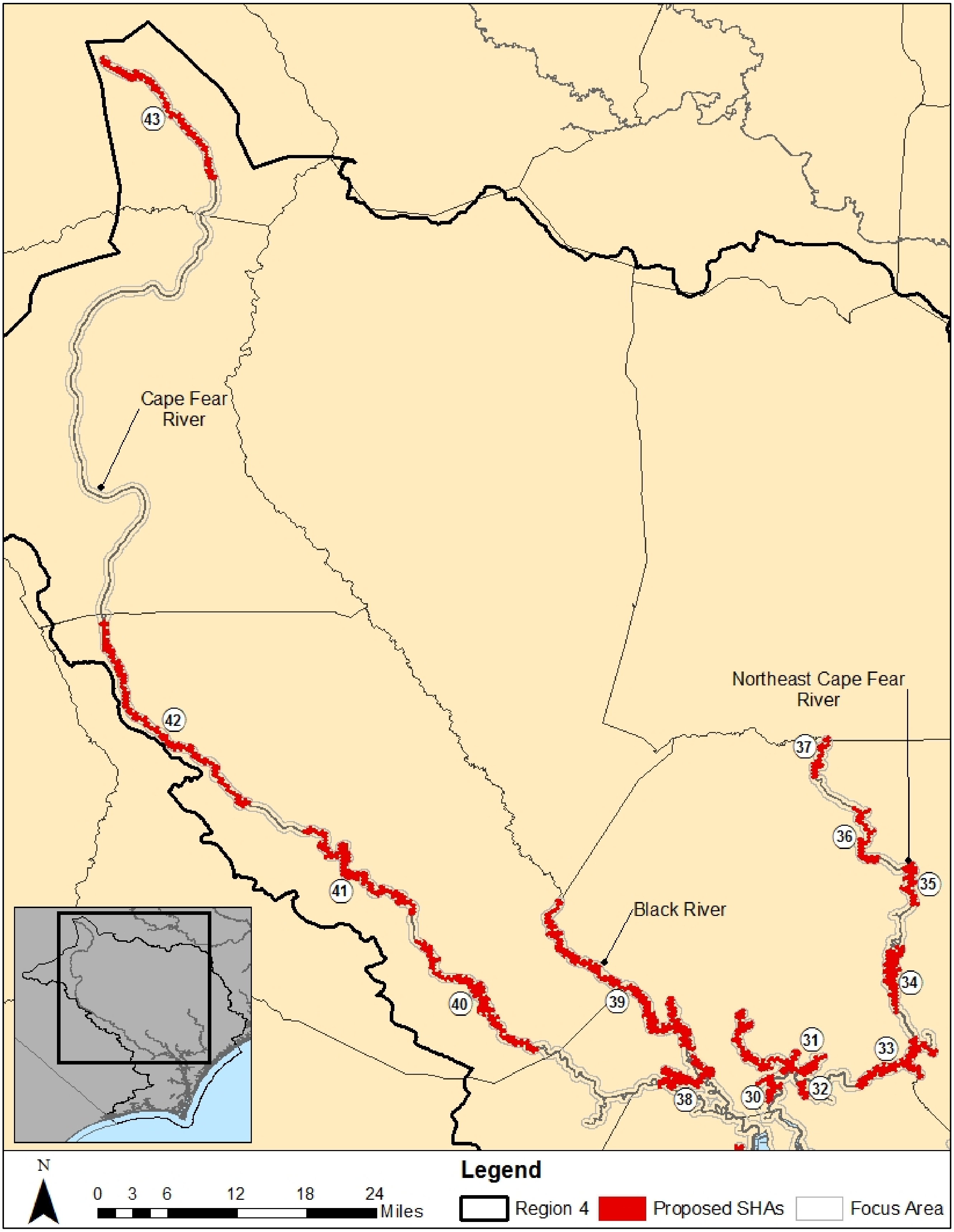
Map 6a. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration.



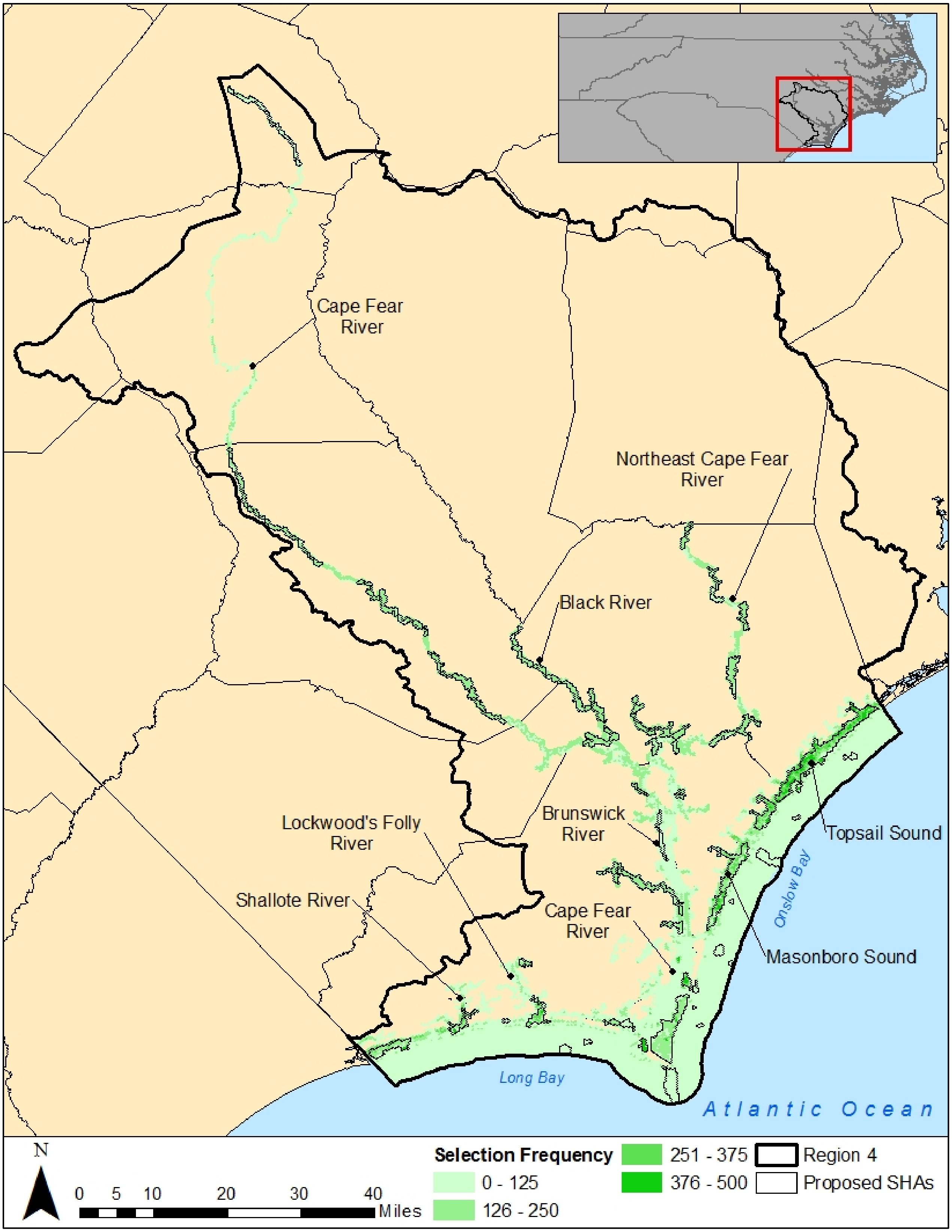
Map 6b. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration, #1-19 and 25-27.



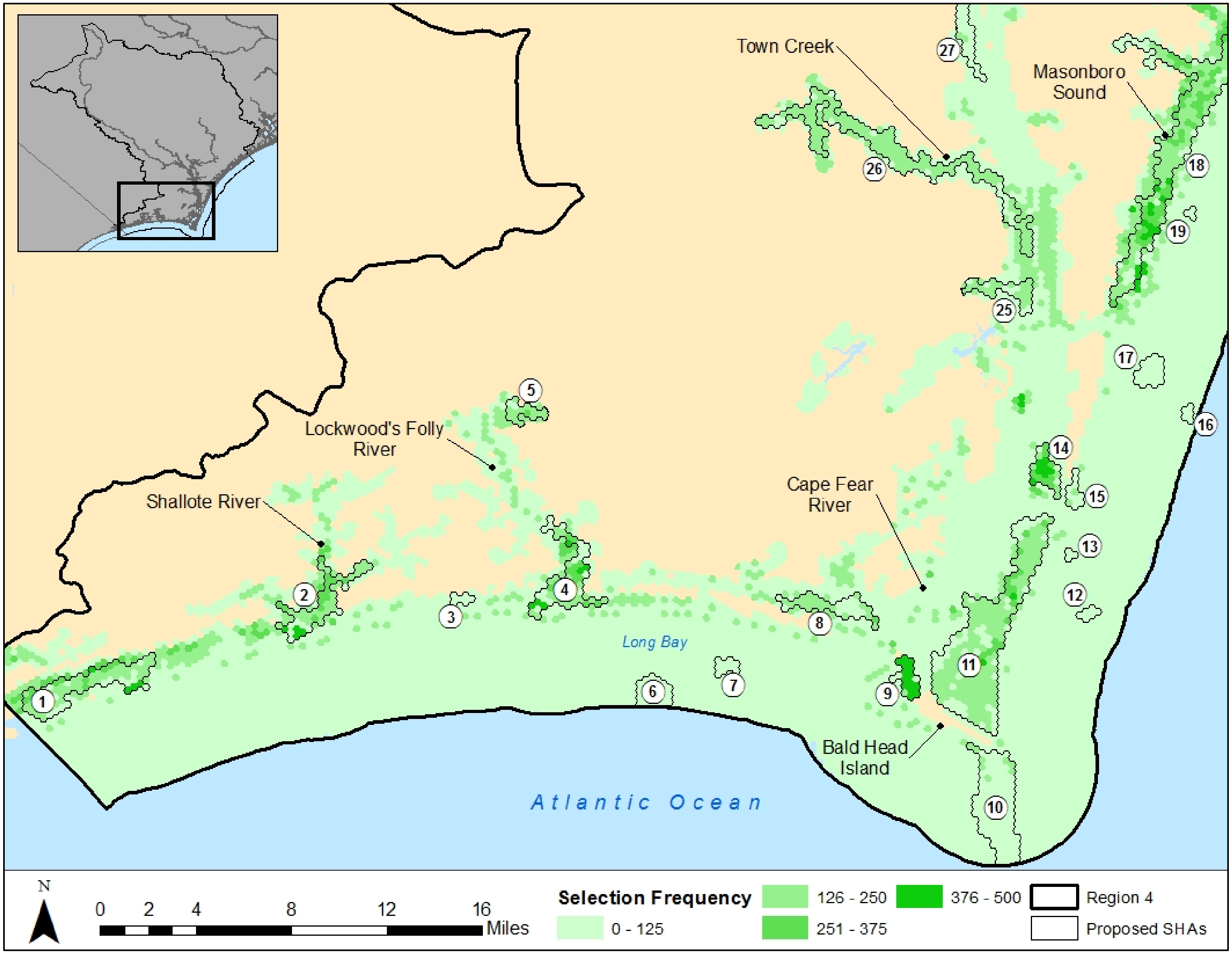
Map 6c. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration, #16-34 and 38-39.



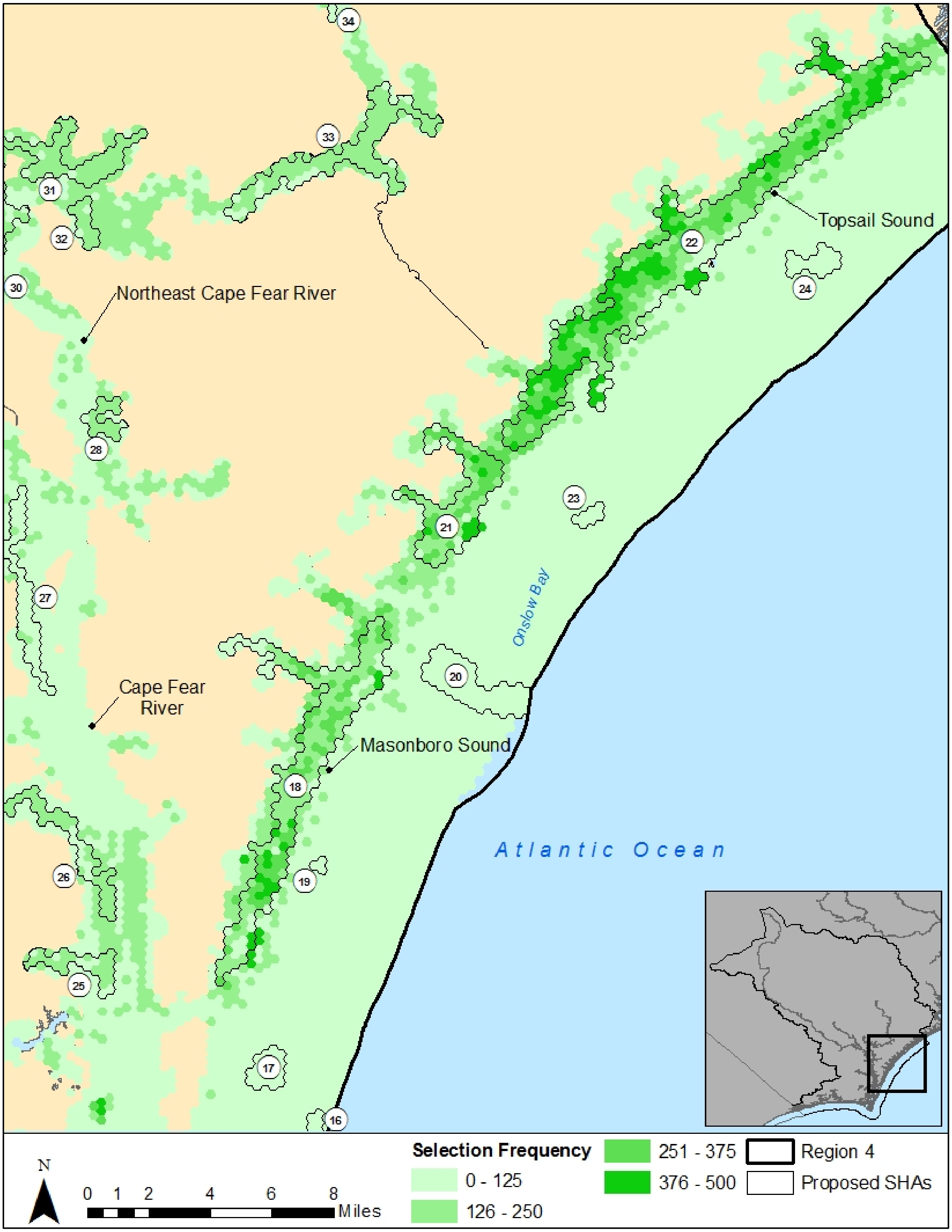
Map 6d. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration., #30-43.



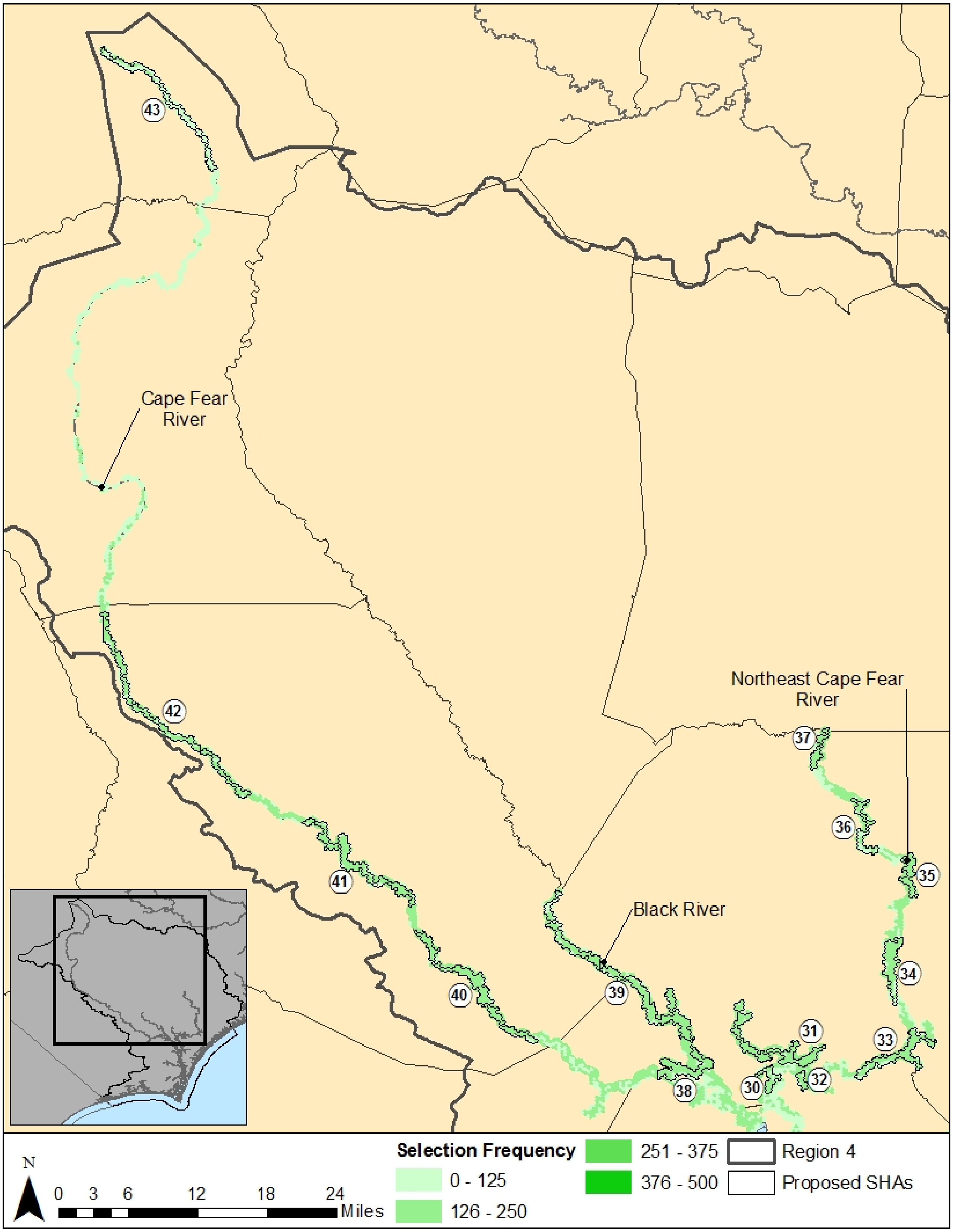
Map 7a. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration.



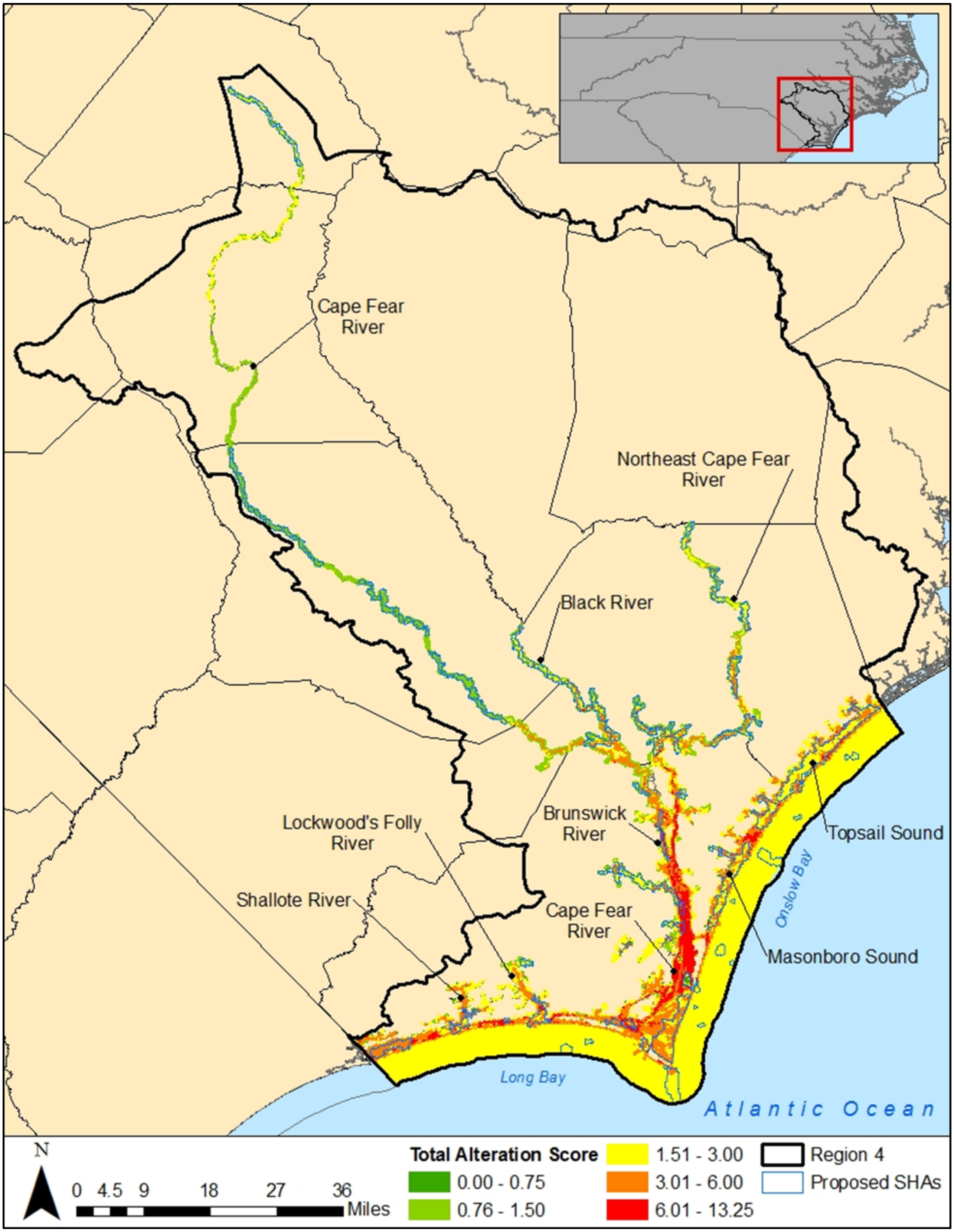
Map 7b. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #1-18 and 25-27.



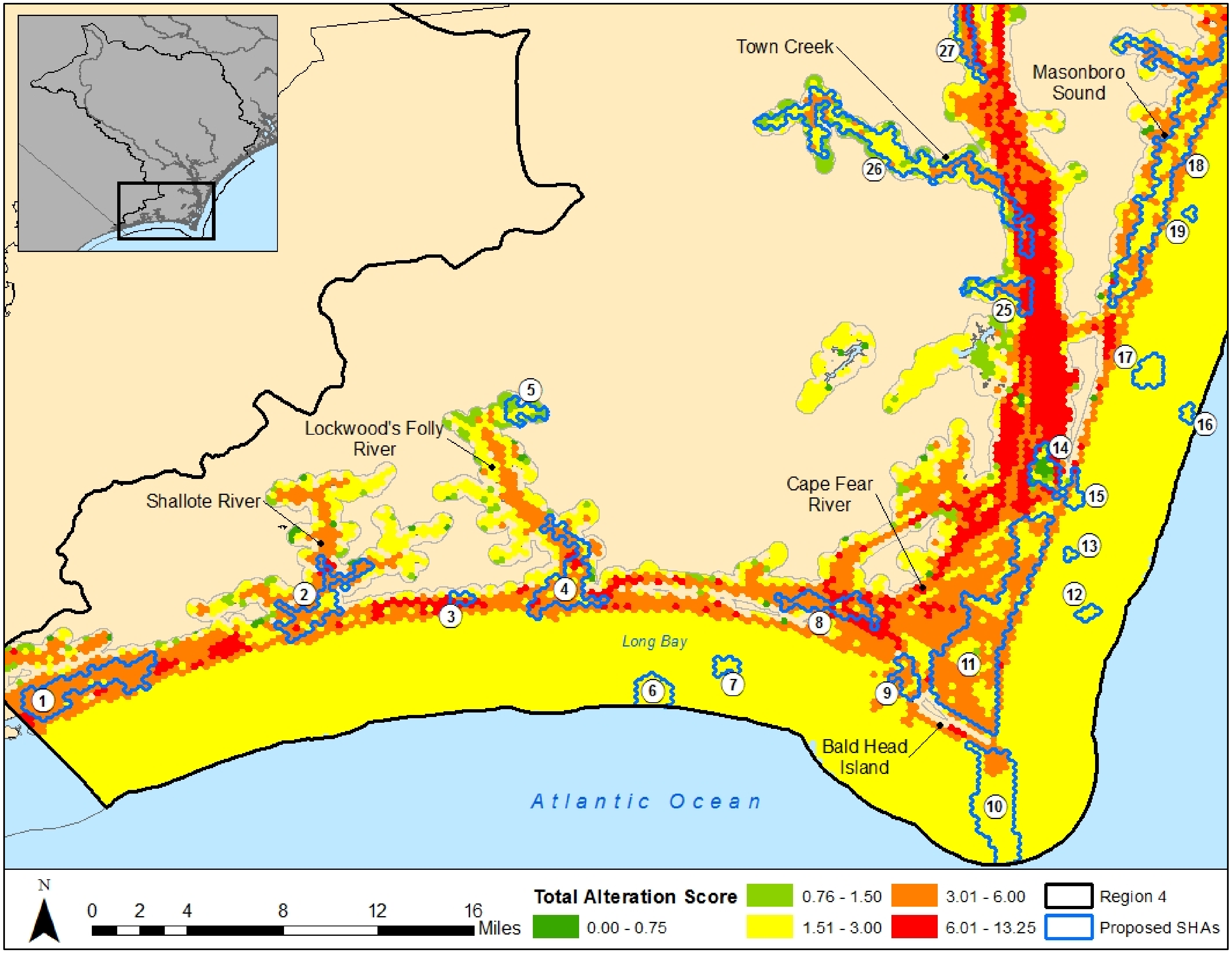
Map 7c. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #16-28 and 30-34.



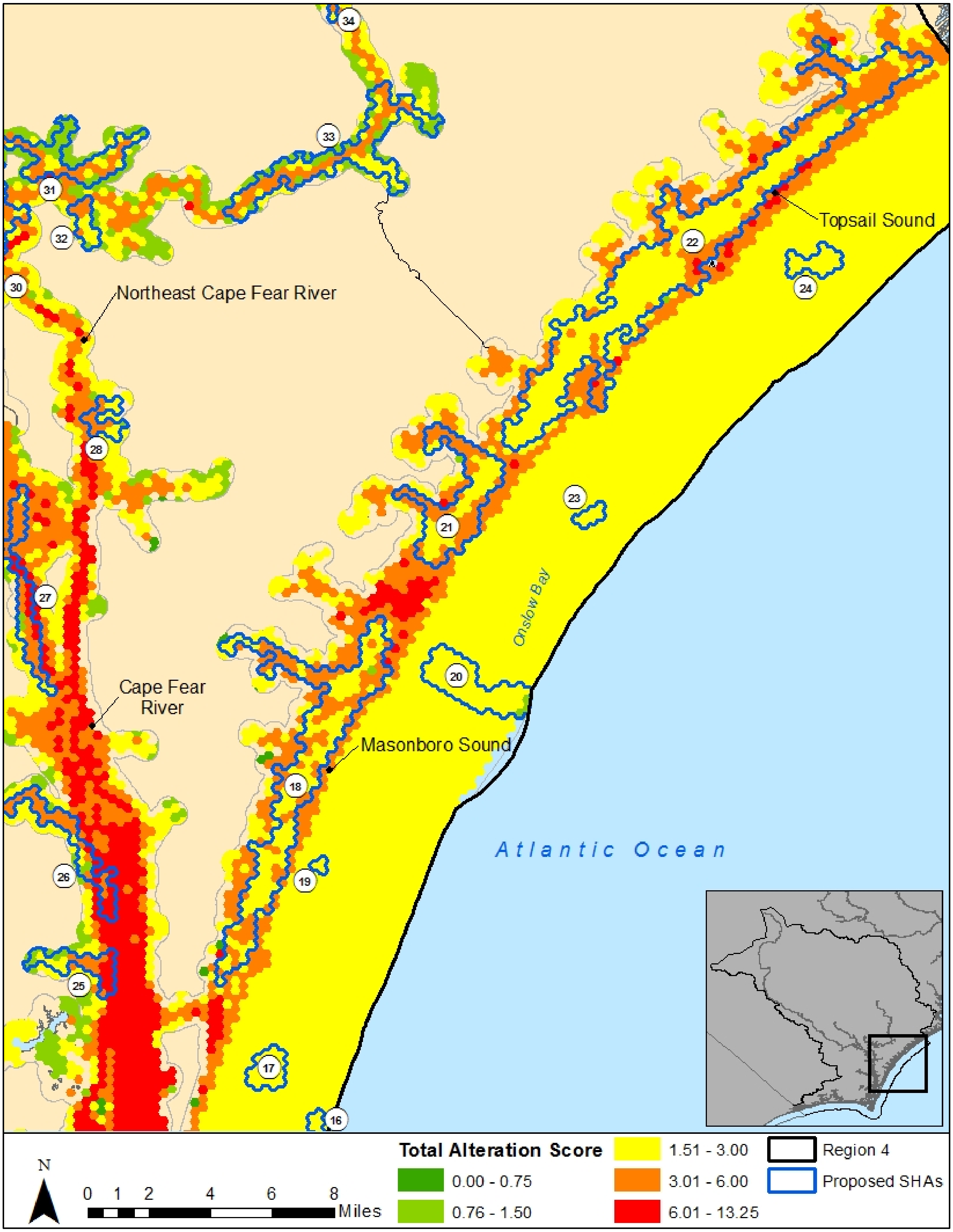
Map 7d. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #30-43.



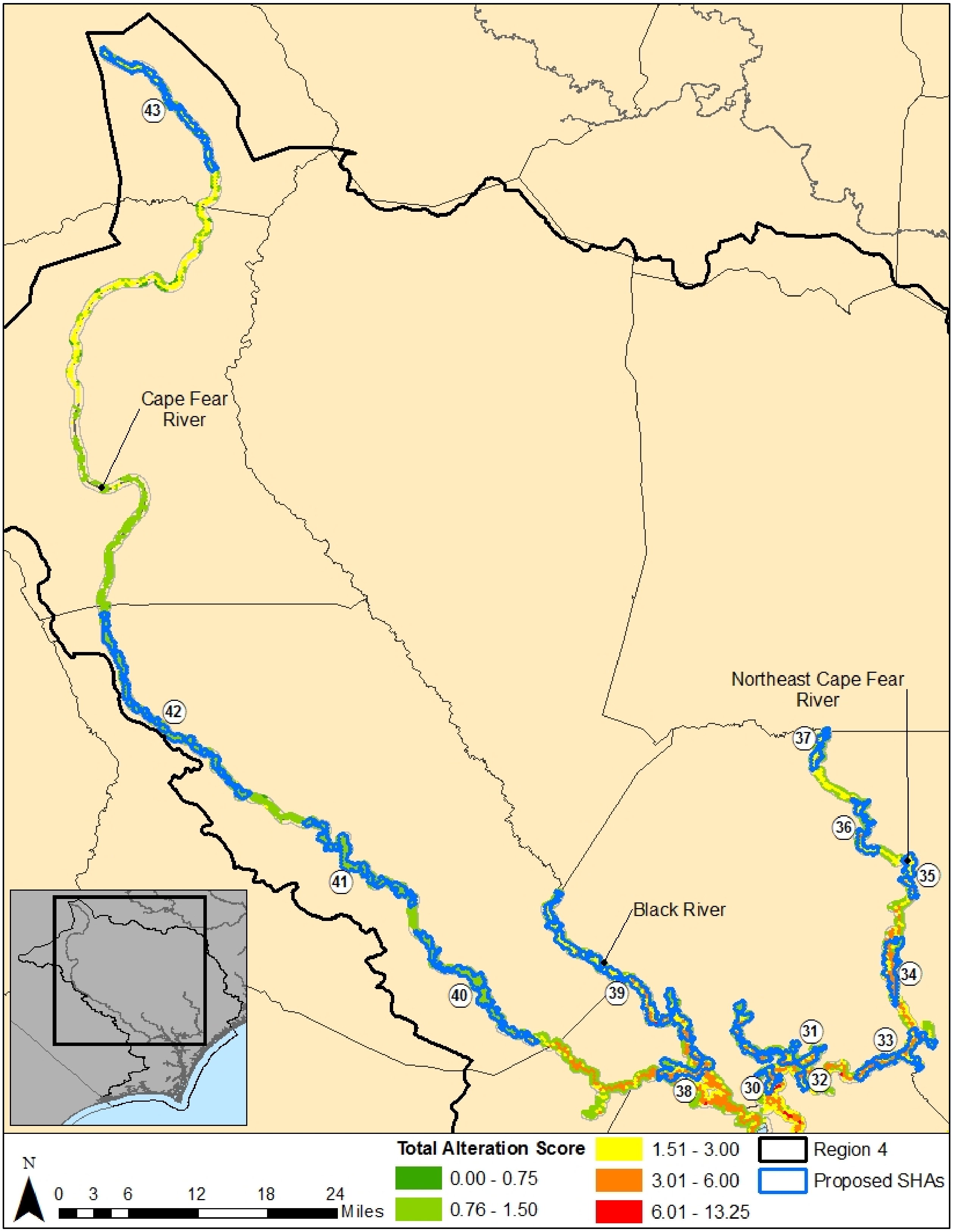
Map 8a. Alteration scores of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration.



Map 8b. Total alteration scores for Region 4 with Strategic Habitat Area (SHA) nominations post-corroboration, #1-18 and 25-27. Higher values equate to greater degradation.



Map 8c. Total alteration scores for Region 4 with Strategic Habitat Area (SHA) nominations post-corroboration, #16-28 and 30-34. Higher values equate to greater degradation.



Map 8d. Total alteration scores for Region 4 with Strategic Habitat Area (SHA) nominations post-corroboration, #30-43. Higher values equate to greater degradation.

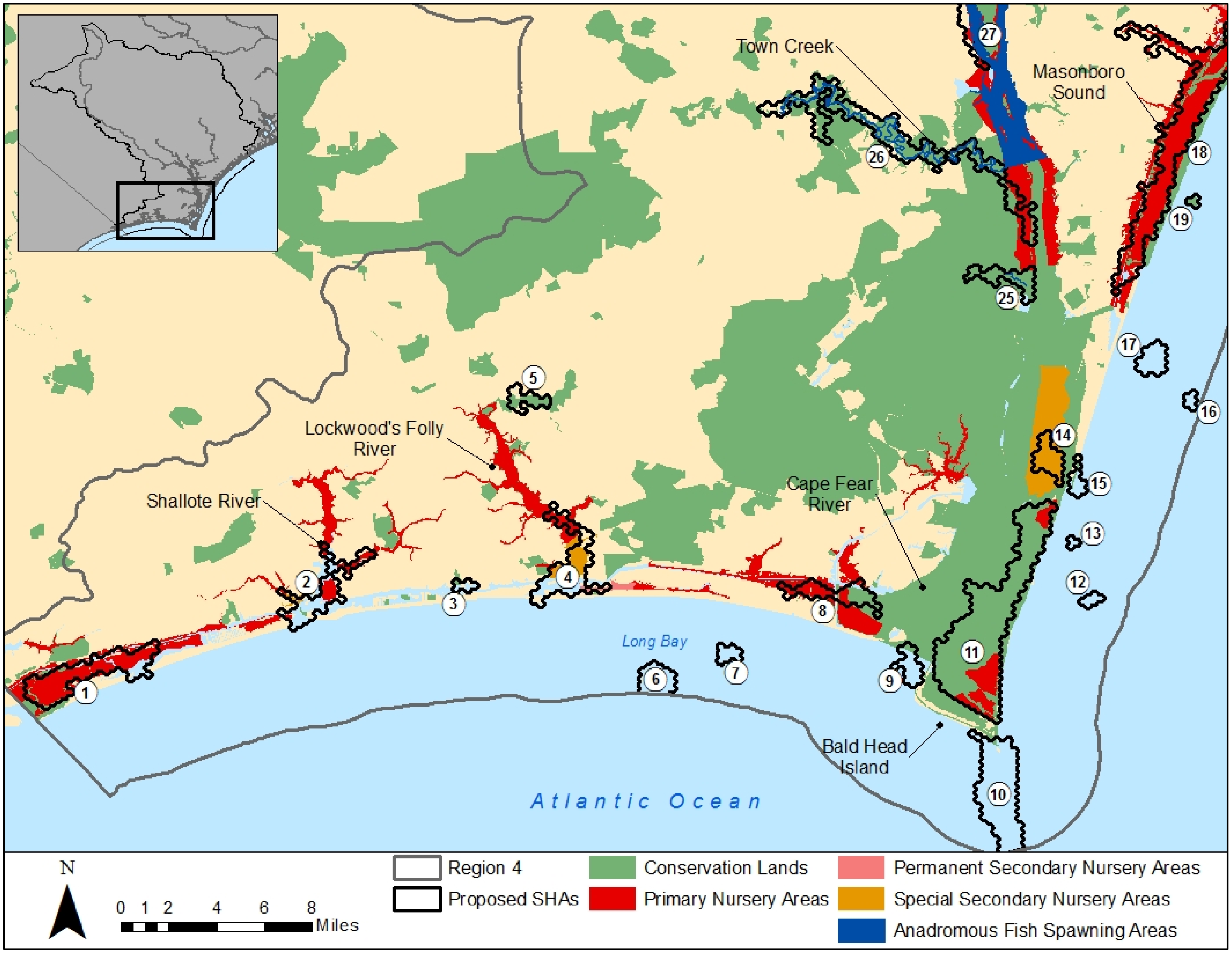
The final SHA selections form a network of priority areas for protection and enhancement ranging from the headwaters of the Cape Fear River to the grass beds and marsh lands of the sounds and inlets. Selections were scattered throughout the area and concentrated in the sounds, tidal creeks, and river headwaters. The advisory committee considered these selections to be appropriate since it is a critical habitat for the majority of the priority species, is a unique habitat feature of North Carolina that is known to contribute significantly to the diversity of fish life in the region, and is a habitat easily lost from physical disturbance (dredging) or water quality degradation. Shell bottom was also set with high representation levels due to their ecological and fishery importance in the area. A large amount of subtidal shell bottom (74%) and intertidal oysters (67.5%) were selected.

Maintaining open shellfish harvest waters is a priority for this region. There are only a few mainland tidal creeks that remain partially open to shellfish harvest including Virginia, Topsail, and Pages creeks and Lockwoods Folly and Shallotte rivers. These areas were selected in the SHA nomination process and should be prioritized for water quality and habitat protections, restoration, and enhancement.

Region 4 has an abundance of state and federally protected lands bordering coastal waters (Maps 9a-d). Of the 74,451 acres selected as SHAs, 74.8% (55,717 acres) already have some level of protection. Of these protections, 42.5% (31,623 acres) of SHAs occur on lands managed for conservation (state, federal, local), 25.8% (19,220 acres) are in MFC designated Primary Nursery Areas (PNAs), 0.4% (272 acres) are in Permanent Secondary Nursery Areas (PSNAs), and 6.2% (4,602 acres) are designated Anadromous Fish Spawning Areas (AFSAs). Some of the larger conservation lands along the coast include Lea Island, Zeke Island, and Masonboro NERRs, and along the rivers, Black River Preserve, Bladen Lake State Forest, and Holly Shelter. Strategic Habitat Areas within protected conservation lands are basically already protected from degradation associated with development, but can be impacted from water-based activities or water quality degradation. The remaining 25.2% (18,734 acres) represent SHA nominations of various conditions that are currently vulnerable to land and/or water based threats.

Region 4 has been the focus of many anadromous fish studies and restoration activities. Efforts are underway to create anadromous fish passage around the three lock and dams on the Cape Fear River mainstem. Protection, restoration, and enhancement of riparian wetlands and water quality in the SHAs along the river will further enhance conditions needed to sustain all life stages of anadromous fish in Region 4.

Map 9a. Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, noting occurrence of Marine Fisheries Commission (MFC) designated nursery areas and state, federal, and private (land trust) conservation lands.



Map 9b. Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #1-18 and 25-27, noting occurrence of Marine Fisheries Commission (MFC) designated nursery areas and state, federal, and private (land trust) conservation lands.

Map 9c. Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #16-28 and 30-34, noting occurrence of Marine Fisheries Commission (MFC) designated nursery areas and state, federal, and private (land trust) conservation lands.

Map 9d. Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #30-43, noting occurrence of Marine Fisheries Commission (MFC) designated nursery areas and state, federal, and private (land trust) conservation lands.

5 FINAL STRATEGIC HABITAT AREA NOMINATIONS

Strategic Habitat Areas are described below beginning in at the South Carolina line and moving up to Topsail Sound and the Surf City bridge and then up the Cape Fear River system. Strategic Habitat Areas with average alteration scores less than 2.00 and selection frequencies greater than 200 (on a scale of 0-500) represent sites with the least extent of alteration and high ecosystem value. In some cases, areas without these criteria were still selected as SHAs due to other outstanding features.

The final SHA nominations are listed below grouped by area and are not in sequential order (Tables 8-13). Acreage, prominent habitat, and corroborating data are noted. Impaired waters rated as Category 5 require a total maximum daily load (TMDL), while those rated as Category 4 do not. Impairment can be due to loss of one or more water quality uses including shellfish harvest, aquatic life, fish consumption, recreation, or water supply.

Water quality classifications include:

- High Quality Waters (HQWs) – waters which are rated excellent based on biological and physical/chemical characteristics through DWR monitoring or special studies, primary nursery areas designated by the MFC, and other functional nursery areas designated by the MFC).
- Outstanding Resource Waters (ORWs) – a subset of HQWs, intended to protect unique and special waters having excellent water quality and being of exceptional state or national ecological or recreational significance. ORWs must be rated excellent by DWR and have one of the following; outstanding fish habitat and fisheries, unusually high level of water-based recreation or potential for such kind of recreation, some special designation such as North Carolina Natural and Scenic River or National Wildlife Refuge, important component of state or national park or forest or special ecological or scientific significance).
- Class SA Waters – a subset of HQW, waters that are used for commercial shellfish harvest or marketing purposes.
- Class SB Waters (SB) - tidal salt waters protected for primary recreation, including swimming, skin diving, water skiing, and similar uses involving human body contact.
- Class SC Waters – waters protected for secondary recreation such as fishing, boating, and other activities involving minimal skin contact; fish and noncommercial shellfish consumption; aquatic life propagation and survival; and wildlife.

Following the SHA nomination descriptions, maps 10-34 show the location, NRTS, and corroborating data for each SHA.

5.1 Brunswick County Waters

Table 8. Descriptions and corroborating data for Region 4 Strategic Habitat Area (SHA) nominations in Brunswick county waters (SHA nominations #1-11).

SHA #1 (Map 10)	Sunset Beach
Description	Sunset Beach, Bird Island, Bull, Cooter, and parts of Jinks creeks, and Tubbs Inlet
Acres	2,579
Prominent Habitats	Emergent wetlands, riparian wetland, and estuarine soft bottom (0-3ft)
Ecological Designations	PNA
Conservation Lands	Bird Island Coastal Reserve
Water Quality Ratings	Mostly impaired (Cat 5) and some supporting
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marinas, trawling, and development
Average Total Alteration Score	4.09
Average Selection Frequency	200

SHA #2 (Map 11)	Shallotte Inlet
Description	Shallotte Inlet, mouth of Shallotte River, and Saucepan and Shallotte creeks
Acres	1,253
Prominent Habitats	Emergent wetland, estuarine soft bottom (0-3ft), and intertidal shell bottom
Ecological Designations	PNA and SSNA
Conservation Lands	North Carolina Agricultural Foundation Preserve
Water Quality Ratings	Mostly impaired (Cat 4&5) and some supporting
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marinas, trawling, and drained
Average Total Alteration Score	3.49
Average Selection Frequency	216

SHA #3 (Map 12)	Holden Beach
Description	West of bridge at Holden Beach
Acres	114
Prominent Habitats	Emergent wetlands
Ecological Designations	None
Conservation Lands	Secession maritime forest
Water Quality Ratings	Impaired (Cat 5)
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	4.99
Average Selection Frequency	69

SHA #4 (Map 12)	Lockwoods Folly Inlet and River
Description	Lockwoods Folly Inlet, mouth of Lockwoods Folly River to Rourks Landing and Montgomery Slough
Acres	1,588
Prominent Habitats	Emergent wetlands and estuarine soft bottom (0-3ft)
Ecological Designations	PSNA, SSNA, and PNA
Conservation Lands	Stanly Road Coastal Fringe Forest and Lockwoods Folly River Tidal Wetlands
Water Quality Ratings	Mostly impaired (Cat 4 & 5) and some supporting
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marina, trawling, and drained
Average Total Alteration Score	4.05
Average Selection Frequency	206

SHA #5 (Map 13)	Lockwoods Folly River
Description	Lockwoods Folly River northeast of Supply
Acres	328
Prominent Habitats	Forested wetland
Ecological Designations	PSNA and SSNA
Conservation Lands	Lockwoods Folly River Tidal Wetlands
Water Quality Ratings	Some supporting
Water Quality Classifications	SA and HQW
Fish Data	None
Prominent Alterations	Major NPDES
Average Total Alteration Score	1.56
Average Selection Frequency	170

SHA #6 (Map 14)	Artificial Reef 430
Description	8.3 nm from Cape Fear River sea buoy, 6.7 nm from Oak Island Light, 3.8 nm from Lockwood's Folly Inlet sea buoy
Acres	776
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Trawling and major NPDES
Average Total Alteration Score	1.97
Average Selection Frequency	None

SHA #7 (Map 14)	**Yaupon Beach Reef – Artificial Reef 425**
Description	6.3 nm from Lockwoods Folly Inlet, 3.8 nm from Oak Island Light, and 7.4 nm from Cape Fear River sea buoy
Acres	293
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Trawling and major NPDES
Average Total Alteration Score	2.00
Average Selection Frequency	None

SHA #8 (Map 15)	**Caswell Beach**
Description	East of Hickory Point, parts of Elizabeth River, and Denis and Dutchman creeks
Acres	1,139
Prominent Habitats	Emergent wetlands and estuarine soft bottom (0-3ft)
Ecological Designations	PNA
Conservation Lands	Lower Cape Fear River Aquatic Habitat, North Carolina Submerged Lands, and North Carolina Coastal Land Trust Preserve
Water Quality Ratings	Impaired (Cat 5)
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120, 510, and 915
Prominent Alterations	Major NPDES, marinas, trawling, and drained
Average Total Alteration Score	5.17
Average Selection Frequency	139

SHA #9 (Maps 15 and 17)	**Cape Fear River Inlet**
Description	Cape Fear River Inlet
Acres	550
Prominent Habitats	Estuarine and marine soft bottom (>6ft)
Ecological Designations	PNA
Conservation Lands	Portions of Bald Head Island, Fort Caswell Dunes and Marshes, and Lower Cape Fear River Aquatic Habitat
Water Quality Ratings	Some supporting
Water Quality Classifications	SA and HQW
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	3.59
Average Selection Frequency	411

SHA #10 (Map 16)	**Frying Pan Shoal**
Description	Frying Pan shoal off Bald Head Island
Acres	1,050
Prominent Habitats	Marine soft bottom (>6ft)
Ecological Designations	Essential Fish Habitat and Habitat of Particular Concern
Conservation Lands	Bald Head Island
Water Quality Ratings	Some supporting
Water Quality Classifications	SA and HQW
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.33
Average Selection Frequency	None

SHA #11 (Maps 16 and 17)	**Bald Head Island**
Description	Bald Head Island to Fort Fisher State Recreation Area
Acres	6,864
Prominent Habitats	Emergent wetland and estuarine soft bottom (0-3ft)
Ecological Designations	TNPA and PNA
Conservation Lands	Bald Head Island State Natural Area, Zeke's Island Estuarine Sanctuary, Fort Fisher State Recreation Area, and Military Ocean Terminal Sunny Point
Water Quality Ratings	Mostly supporting and some impaired (Cat 5)
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120, 510, and 915
Prominent Alterations	Major NPDES, drainage, trawling, and minor NPDES
Average Total Alteration Score	3.19
Average Selection Frequency	163

5.2 New Hanover and Pender County Waters

Table 9. Descriptions and corroborating data for Region 4 Strategic Habitat Area (SHA) nominations in New Hanover and Pender county waters (SHA nominations #12-24).

SHA #12 (Map 17)	**Hard bottom off Fort Fisher Beach State Park**
Description	Hard bottom off Fort Fisher Beach State Park
Acres	195
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

SHA #13 (Map 17)	**Sheepshead Rock**
Description	8.7 nm from Carolina Beach Inlet buoy
Acres	98
Prominent Habitats	Soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.04
Average Selection Frequency	None

SHA #14 (Map 18)	**Cape Fear River at Sunny Point**
Description	Cape Fear river behind Fort Fisher, adjacent to Sunny point ocean terminal
Acres	755
Prominent Habitats	Subtidal shell bottom and estuarine soft bottom (0-3ft)
Ecological Designations	SSNA
Conservation Lands	Lower Cape Fear River aquatic habitat, MOTSU Buffer zone natural area, and Military Ocean Terminal Sunny Point
Water Quality Ratings	Some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	DMF Programs 120, 510, and 915
Prominent Alterations	Major NPDES, marinas, trawling, and minor NPDES
Average Total Alteration Score	2.62
Average Selection Frequency	303

SHA #15 (Map 18)	**Fort Fisher Cocquina Outcrop**
Description	Fort Fisher Cocquina outcrop
Acres	304
Prominent Habitats	Marine soft bottom (>6ft) and hard bottom
Ecological Designations	None
Conservation Lands	MOTSU buffer zone natural area, Fort Fisher Cocquina outcrop, and Fort Fisher State Historic Site
Water Quality Ratings	Some Supporting
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	3.12
Average Selection Frequency	None

SHA #16 (Map 18)	**AR – 378B**
Description	4.3 nm from Carolina Beach Inlet sea buoy
Acres	163
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

SHA #17 (Map 18)	**Phillip Wolfe Reef – AR-378**
Description	3.2 nm from Carolina Beach Inlet buoy
Acres	618
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

SHA #18 (Map 19)	**Masonboro Island**
Description	Masonboro Island including Hewletts Creek
Acres	5,667
Prominent Habitats	Emergent wetland and estuarine soft bottom (0-3ft) and (ND)
Ecological Designations	PNA
Conservation Lands	Masonboro Island National Estuarine Research Reserve, Masonboro Island State Natural Area, and New Hanover Conservation Lands
Water Quality Ratings	Some supporting and some impaired (Cat 5)
Water Quality Classifications	SA, HQW, and ORW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Marinas and major NPDES
Average Total Alteration Score	3.11
Average Selection Frequency	221

SHA #19 (Map 19)	**Masonboro Outcrop**
Description	3.6 nm from the Carolina Beach Inlet buoy
Acres	97
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	Masonboro outcrop
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.02
Average Selection Frequency	None

SHA #20 (Map 19)	**Meares Harris – AR-370**
Description	2.3 nm from Masonboro Inlet sea buoy
Acres	1,696
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	1.93
Average Selection Frequency	None

SHA #21 (Map 20)	**North Wrightsville Beach**
Description	Howe and Pages creeks, and connecting ICW
Acres	2,442
Prominent Habitats	Emergent wetlands, wetland edge, and estuarine soft bottom(0-3ft and ND)
Ecological Designations	PNA, PSNA, and TNPA
Conservation Lands	Howe and Pages creeks natural areas and Figure Eight Island marsh
Water Quality Ratings	Some supporting and some impaired (Cat 5)
Water Quality Classifications	SA, ORW, and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marina, trawling, drained, and development
Average Total Alteration Score	3.28
Average Selection Frequency	251

SHA #22 (Map 21)	**Topsail Beach**
Description	Topsail Beach including Futch Creek, Virginia Creek, Rich Inlet, and New Topsail Inlet
Acres	11,711
Prominent Habitats	Emergent wetlands, wetland edge, and estuarine soft bottom
Ecological Designations	PNA, PSNA, and TNPA
Conservation Lands	Figure Eight Island marsh, Futch and Foy creeks natural areas, Lea-Hutaff Island natural areas, Topsail Sound Maritime Forests
Water Quality Ratings	Mostly supporting and some impaired (Cat 5)
Water Quality Classifications	SA, ORW, and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marinas, and trawling
Average Total Alteration Score	2.81
Average Selection Frequency	302

SHA #23 (Map 20)	**Billy Murrel Reef – AR-364**
Description	6.1 nm from Masonboro Inlet sea buoy and 6.5 nm from New Topsail Inlet sea buoy
Acres	228
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

SHA #24 (Map 21)	**Topsail Reef – AR-360**
Description	2 nm from New Topsail Inlet sea buoy
Acres	553
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	Topsail outcrop
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

5.3 Cape Fear River

Table 10. Descriptions and corroborating data for Region 4 Strategic Habitat Area (SHA) nominations on the main stem of the Cape Fear River (SHA nominations #25, 26, 29, 38, 40-43).

SHA #25 (Map 22)	**Cape Fear River – Lilliput Creek**
Description	Lilliput Creek just north of Sunny point military terminal
Acres	272
Prominent Habitats	Emergent wetlands and riverine soft bottom (0-3ft)
Ecological Designations	PNA and AFSA
Conservation Lands	Blue Pond/Allen Creek, Orton Sandhills and Limesinks, and Lower Cape Fear River Aquatic Habitat
Water Quality Ratings	Mostly no data and some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	DMF Programs 510 and 915
Prominent Alterations	Major NPDES and drained
Average Total Alteration Score	4.41
Average Selection Frequency	149

SHA #26 (Map 22)	**Cape Fear River – Town Creek**
Description	Town Creek including western portion of Cape Fear River to Sand Hill Creek
Acres	3,451
Prominent Habitats	Forested wetland and emergent wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Lower Cape Fear River aquatic habitat, Pleasant Oaks/ Goose Landing Plantations, Town Creek marshes and swamp, North Carolina Coastal Land Trust Easement, Brunswick County Open Space, and North Carolina Clean Water Management Trust Fund Easement
Water Quality Ratings	Mostly no data and some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	DMF Programs 120, 510, and 915 and WRC annual spawning stock survey
Prominent Alterations	Major NPDES and drained
Average Total Alteration Score	3.05
Average Selection Frequency	155

SHA #29 (Map 24)	**Cape Fear River – Indian Creek**
Description	Cape Fear River at mouth of Indian Creek to convergence of Otter Branch and Mulberry Branch
Acres	364
Prominent Habitats	Forested wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	None
Water Quality Ratings	Mostly no data and some supporting
Water Quality Classifications	None
Fish Data	DMF Program 120 and WRC IBI sampling
Prominent Alterations	Major NPDES
Average Total Alteration Score	2.37
Average Selection Frequency	182

SHA #38 (Map 29)	Cape Fear River Lowlands
Description	Cape Fear River including Lyon creek, Crossway Creek and Lyon Thorofare
Acres	2,327
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Lower Black River Swamp and Cape Fear River Wetlands Game Land
Water Quality Ratings	Mostly no data and some supporting
Water Quality Classifications	None
Fish Data	DMF Program 120 and WRC IBI sampling
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	2.40
Average Selection Frequency	160

SHA #40 (Map 31)	Cape Fear River – Kelly
Description	Cape Fear River near Beaverdam Creek and Kelly
Acres	2,680
Prominent Habitats	Forested wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	Cape Fear River Lowlands, Steep Run Swamp, Cape Fear River Kelly Bottomlands, Cape Fear River/ Whitehall Floodplain Forest, North Carolina Coastal Land Trust Easement, Whitehall Plantation Game Land, and Bladen Lakes State Forest
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	WRC IBI sampling and annual spawning stock survey
Prominent Alterations	Major NPDES
Average Total Alteration Score	1.04
Average Selection Frequency	165

SHA #41 (Map 32)	Cape Fear River – Elizabethtown
Description	Cape Fear River including Pemberton Creek and mouth of Mulford Creek
Acres	2,360
Prominent Habitats	Forested wetlands
Ecological Designations	AFSA
Conservation Lands	Cape Fear Sloughs, Walkers Bluff, and Sugar Loaf Springs
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	WRC IBI sampling
Prominent Alterations	Major NPDES
Average Total Alteration Score	0.98
Average Selection Frequency	153

SHA #42 (Map 33)	Cape Fear River – Tarheel
Description	South of Fayetteville on the Cape Fear River
Acres	1,678
Prominent Habitats	Forested wetlands
Ecological Designations	AFSA,
Conservation Lands	Cape Fear River Terraces and North Carolina Coastal Land Trust Preserve
Water Quality Ratings	Mostly supporting
Water Quality Classifications	None
Fish Data	WRC IBI sampling and annual spawning stock survey
Prominent Alterations	Major NPDES
Average Total Alteration Score	1.00
Average Selection Frequency	144

SHA #43 (Map 34)	Cape Fear River – Lillington
Description	North of Fayetteville on the Cape Fear River
Acres	1,002
Prominent Habitats	Riverine soft bottom and forested wetlands
Ecological Designations	AFSA
Conservation Lands	Cape Fear River Canebrakes, Byrd Farm Industrial Park Natural Area, Upper Cape Fear River Aquatic Habitat, and Cape Fear River Park
Water Quality Ratings	Mostly impaired (Cat 5) and some supporting
Water Quality Classifications	None
Fish Data	WRC IBI sampling and annual spawning stock survey
Prominent Alterations	Major NPDES and minor NPDES
Average Total Alteration Score	1.84
Average Selection Frequency	71

5.4 Brunswick River

Table 11. Descriptions and corroborating data for Region 4 Strategic Habitat Area (SHA) nomination on the Brunswick River (SHA nomination #27).

SHA #27 (Map 23)	Brunswick River
Description	Begins south of Eagle Island along western shoreline of Belville and Leland to parts of Alligator Creek and adjacent wetlands
Acres	1,123
Prominent Habitats	Emergent wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	Lower Cape Fear River Aquatic Habitat, Brunswick River/Cape Fear River Marshes, Brunswick County Open Space, and Eagles Island Natural Area
Water Quality Ratings	Mostly impaired (Cat 5) and some no data
Water Quality Classifications	SC
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, minor NPDES, and drained
Average Total Alteration Score	4.92
Average Selection Frequency	84

5.5 Northeast Cape Fear River

Table 12. Descriptions and corroborating data for Region 4 Strategic Habitat Area (SHA) nomination on the Northeast Cape Fear River (SHA nominations #28, 30-37).

SHA #28 (Map 24)	Northeast Cape Fear River – Ness Creek
Description	North of Wilmington near Wrightsboro and Ness creek
Acres	488
Prominent Habitats	Emergent wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain
Water Quality Ratings	Some no data and some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	None
Prominent Alterations	Major NPDES and drained
Average Total Alteration Score	3.03
Average Selection Frequency	162

SHA #30 (Map 25)	Northeast Cape Fear River – Cowpen Branch
Description	Northeast Cape Fear River including Cowpen Branch
Acres	678
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain
Water Quality Ratings	Some no data and some supporting
Water Quality Classifications	None
Fish Data	DMF Program 120
Prominent Alterations	Major NPDES
Average Total Alteration Score	2.31
Average Selection Frequency	150

SHA #31 (Map 25)	Northeast Cape Fear River – Long Creek
Description	Northeast Cape Fear River including Long, Morgans, and Turkey creeks
Acres	2,904
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River floodplain and Cape Fear River Wetlands Game Land
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	DMF Program 120
Prominent Alterations	Major NPDES, marinas, and shellfish closure
Average Total Alteration Score	2.31
Average Selection Frequency	161

SHA #32 (Map 25)	Northeast Cape Fear River – Prince George Creek
Description	Northeast Cape Fear River and mouth of Prince George Creek
Acres	439
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain and Cape Fear River Wetlands Game Land
Water Quality Ratings	Some supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	3.15
Average Selection Frequency	153

SHA #33 (Map 26)	Northeast Cape Fear River – Castle Hayne
Description	Northeast Cape Fear River with portions of Island Creek and Merricks Creek
Acres	2,344
Prominent Habitats	Forested wetland and riverine soft bottom (ND)
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain, Rocky Point Sandhills, North Carolina Coastal Land Trust Preserve and Easement
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	DMF Program 120
Prominent Alterations	Major NPDES, marinas, shellfish closure, and drained
Average Total Alteration Score	2.67
Average Selection Frequency	150

SHA #34 (Map 26)	Northeast Cape Fear River – Rocky Point
Description	Northeast Cape Fear River with portions of Pike, Mcintre and Lillington creeks
Acres	1,741
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain and Cape Fear River Wetlands Game Land
Water Quality Ratings	Mostly supporting, some no data, and some impaired (Cat 5)
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES, marinas, and shellfish closure
Average Total Alteration Score	2.86
Average Selection Frequency	149

SHA #35 (Map 27)	**Northeast Cape Fear River – Ashes Creek**
Description	Northeast Cape Fear River with Ashes Creek
Acres	461
Prominent Habitats	Forested wetland
Ecological Designations	AFSA
Conservation Lands	Northeast Cape Fear River Floodplain, Holly Shelter Game Land, and North Carolina Coastal Land Trust Easement
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	2.20
Average Selection Frequency	178

SHA #36 (Map 27 and 28)	**Northeast Cape Fear River – Watermelon Run**
Description	Northeast Cape Fear River at Watermelon Run
Acres	741
Prominent Habitats	Forested wetland
Ecological Designations	AFSA
Conservation Lands	None
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marina
Average Total Alteration Score	2.30
Average Selection Frequency	129

SHA #37 (Map 28)	**Northeast Cape Fear River – Duplin/Pender County Line**
Description	Northeast Cape Fear River at the Duplin/Pender county line
Acres	607
Prominent Habitats	Forested wetland
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	2.14
Average Selection Frequency	184

5.6 Black River

Table 13. Descriptions and corroborating data for Region 4 Strategic Habitat Area (SHA) nomination on the Black River (SHA nomination #39).

SHA #39 (Map 30)	Black River
Description	Black River including mouth of Moores Creek
Acres	4,783
Prominent Habitats	Forested wetland
Ecological Designations	AFSA
Conservation Lands	Lower Black River Swamp, Black River Cypress Swamp, Upper Black River Bottomlands, Cape Fear River Wetlands Game Land, and Black River Preserve
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	WRC IBI sampling
Prominent Alterations	Major NPDES, marinas, and shellfish closure
Average Total Alteration Score	2.33
Average Selection Frequency	158

6 MAPS OF FINAL INDIVIDUAL STRATEGIC HABITAT AREAS

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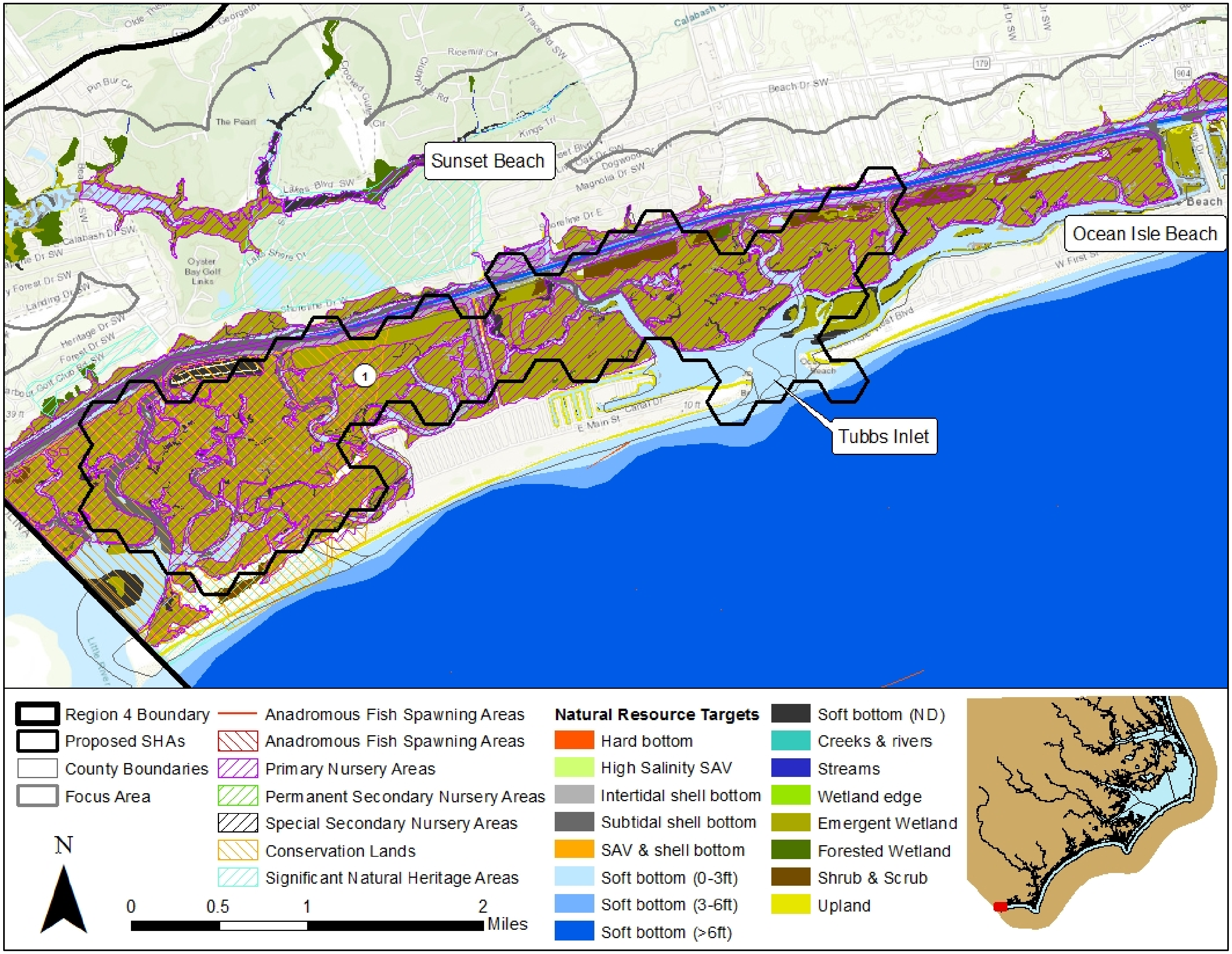
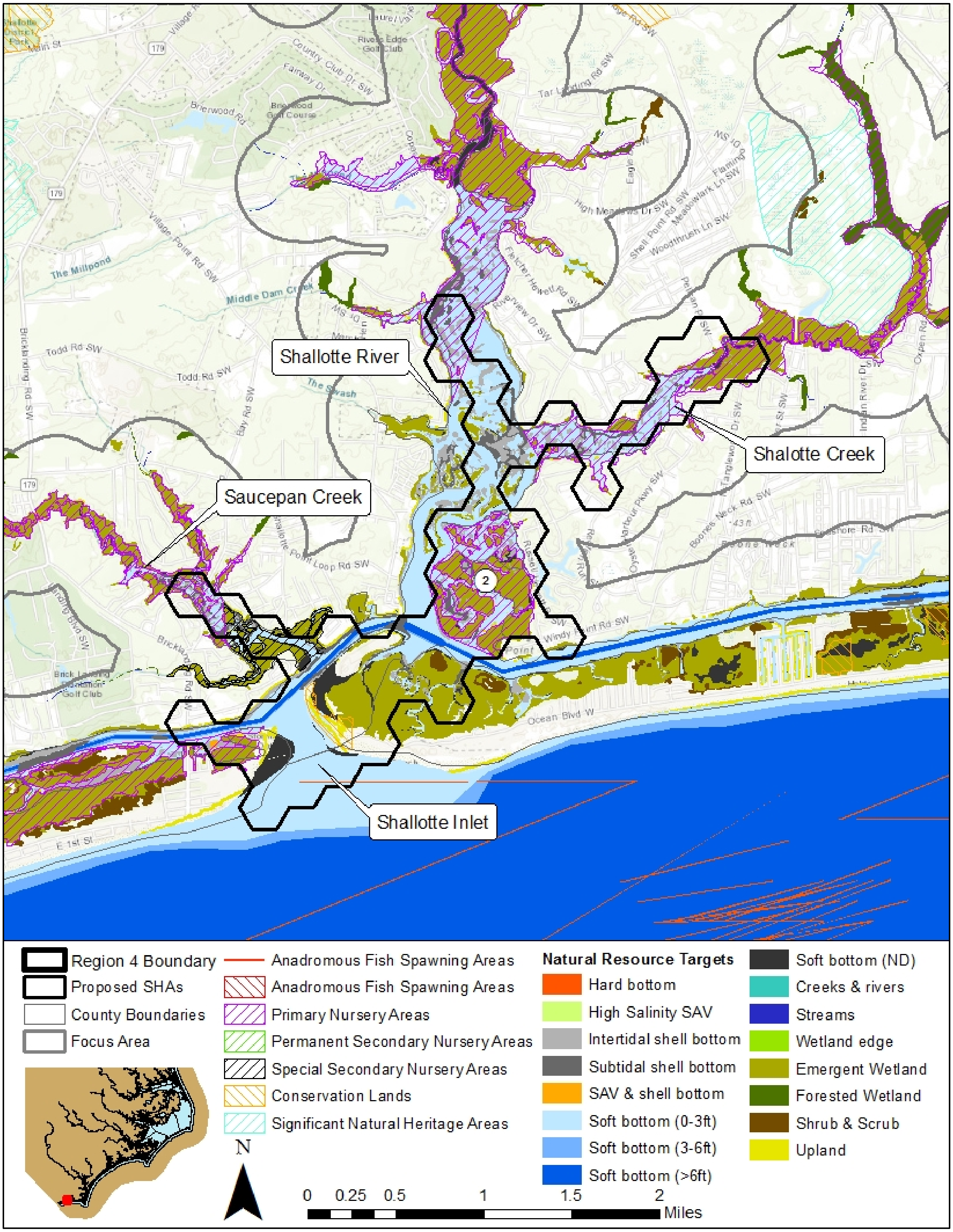
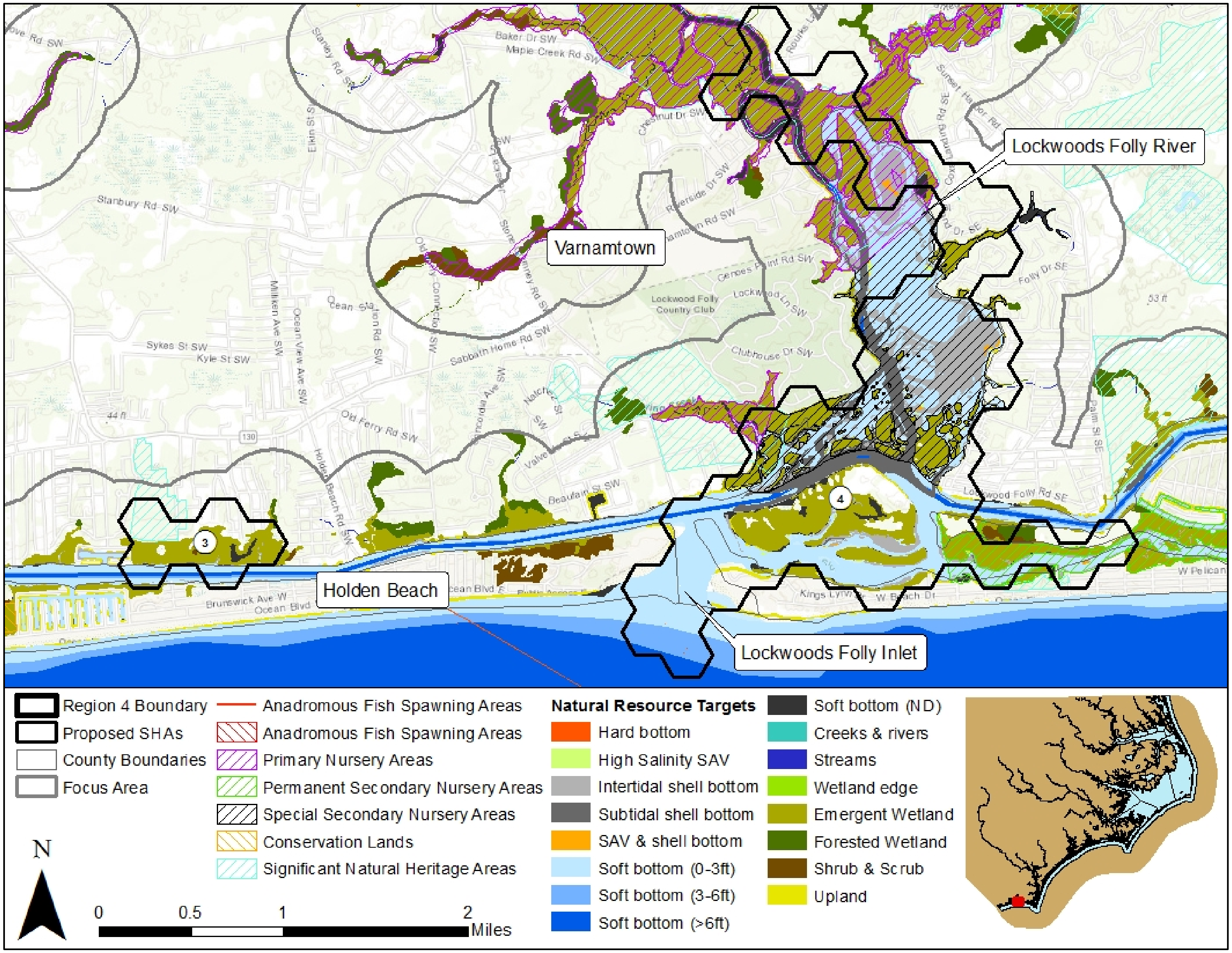


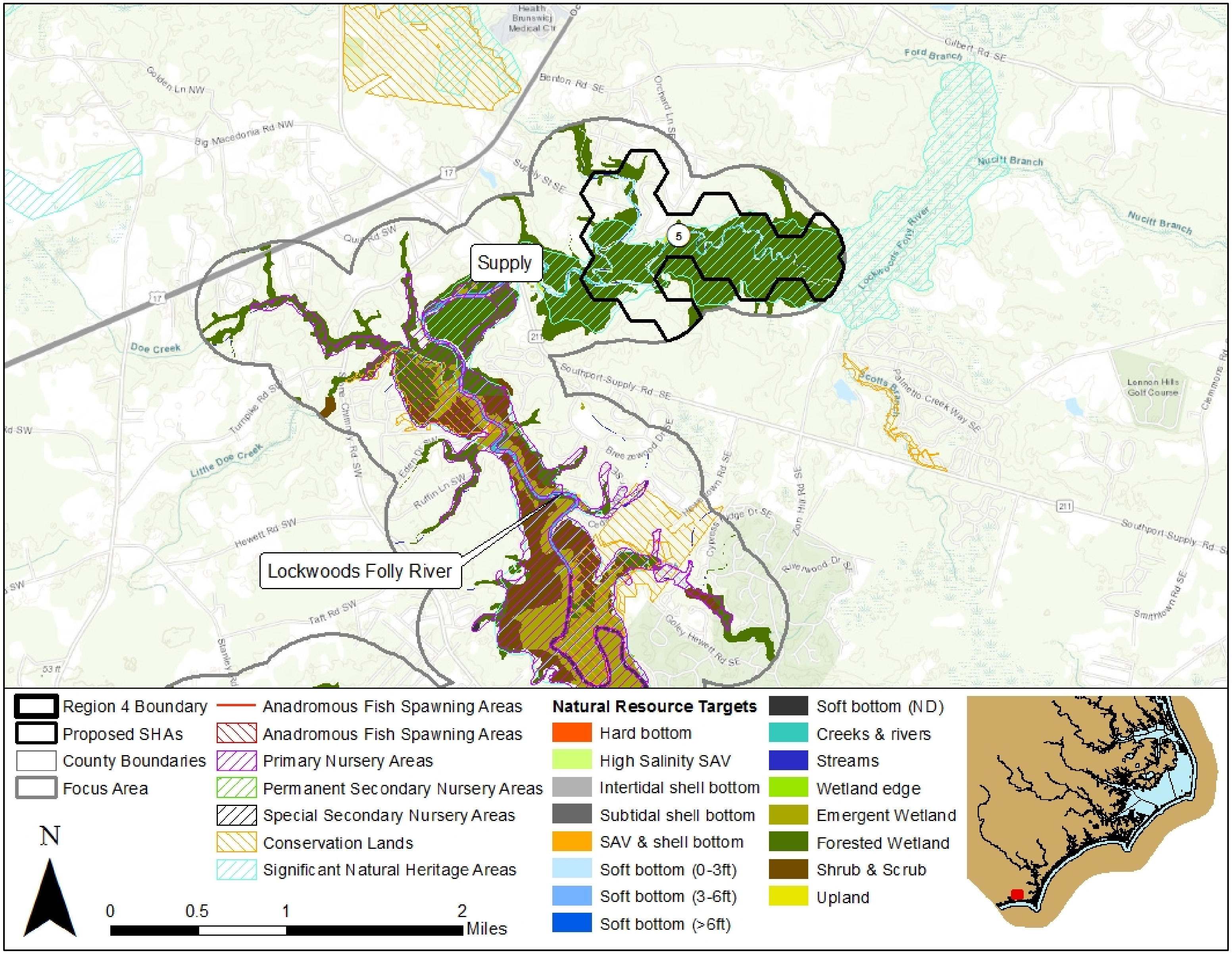
Map 10. Draft Strategic Habitat Area (SHA) nomination #1, Sunset Beach – Bird Island to Tubbs Inlet.



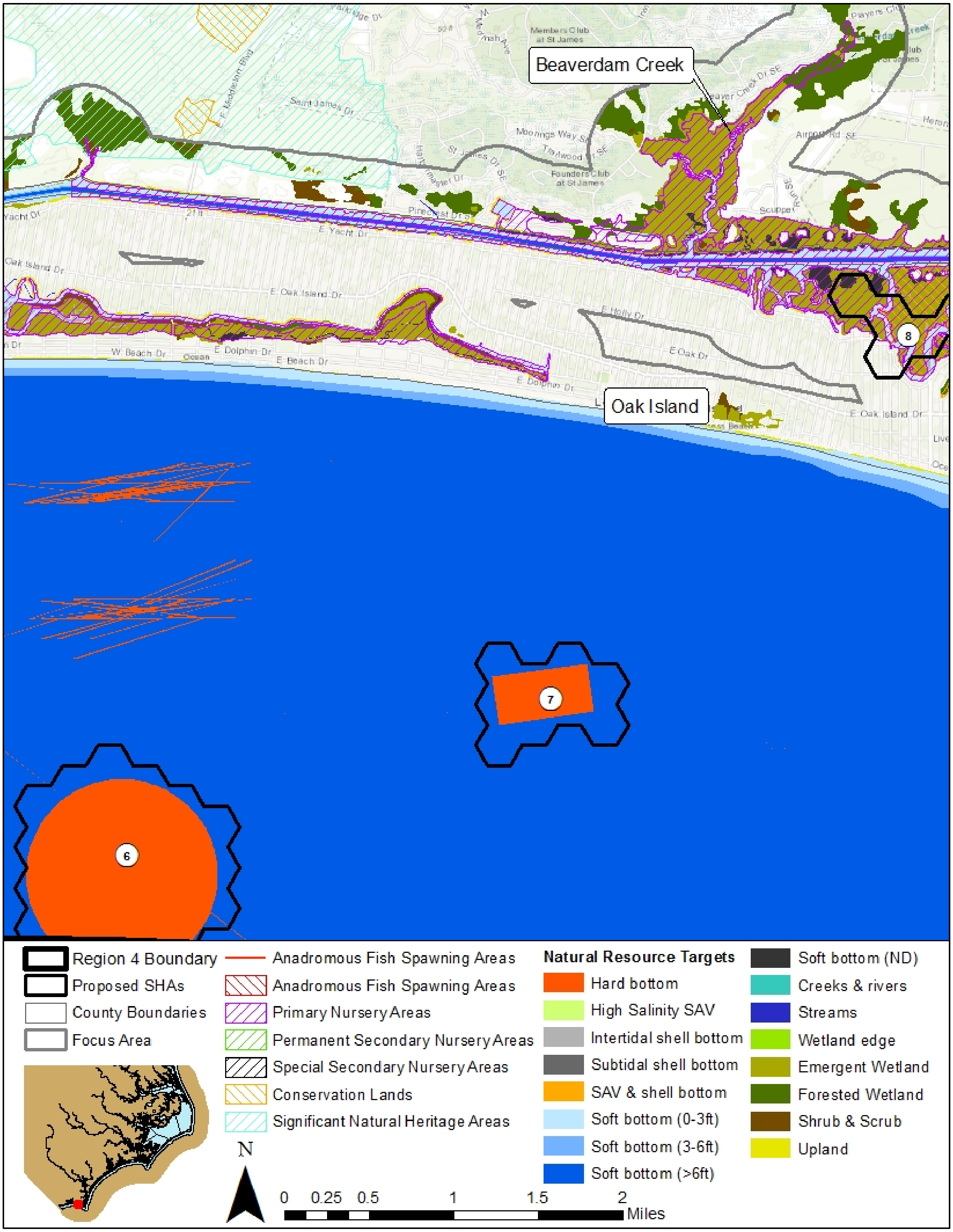
Map 11. Draft Strategic Habitat Area (SHA) nomination #2 – Shallotte Inlet, mouth of Shallotte River, and Shallotte Creek.



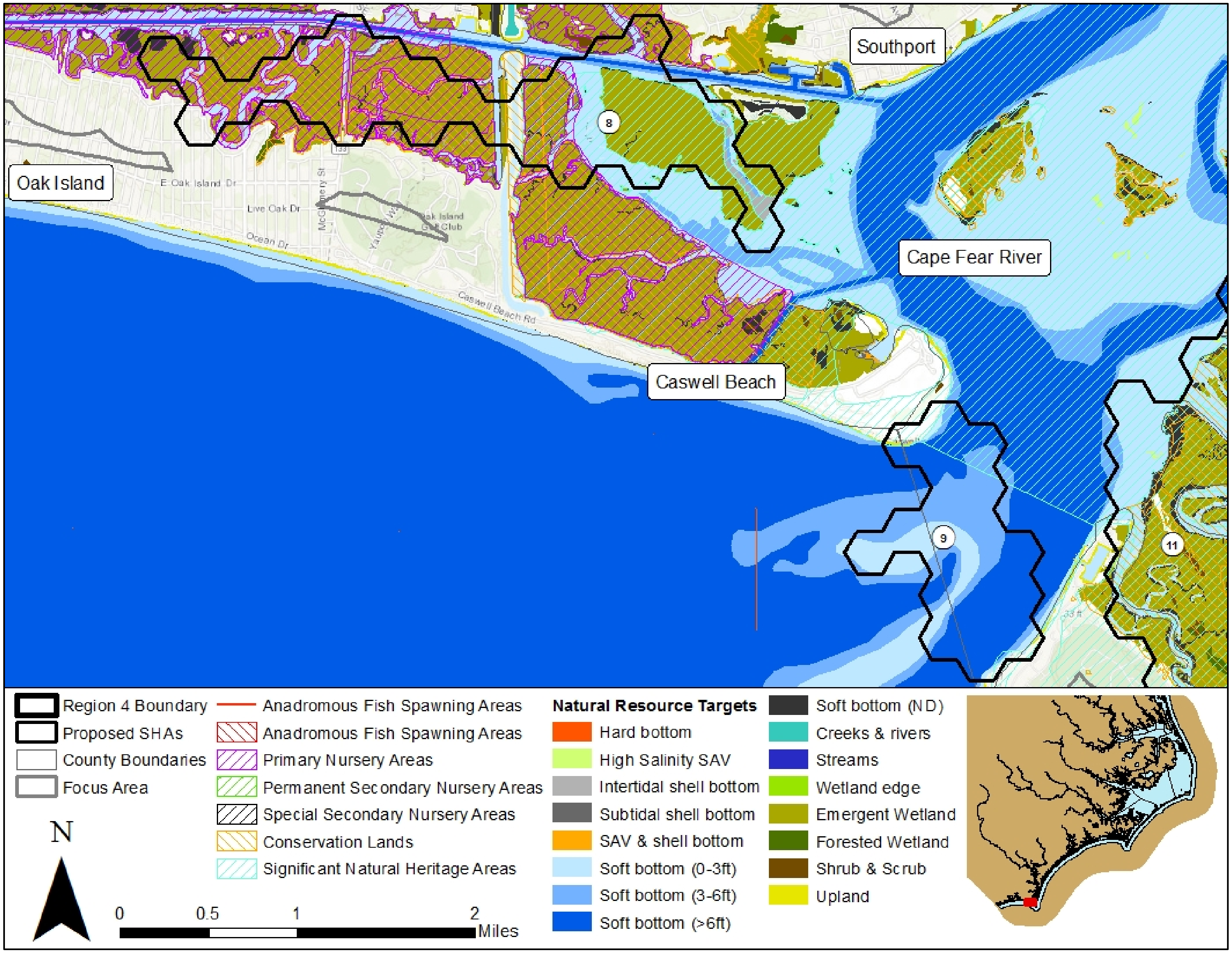
Map 12. Draft Strategic Habitat Area (SHA) nominations #3 – Holden Beach and #4 – Lockwoods Folly Inlet, mouth of Lockwoods Folly River to Rourks Landing and Montgomery Slough.



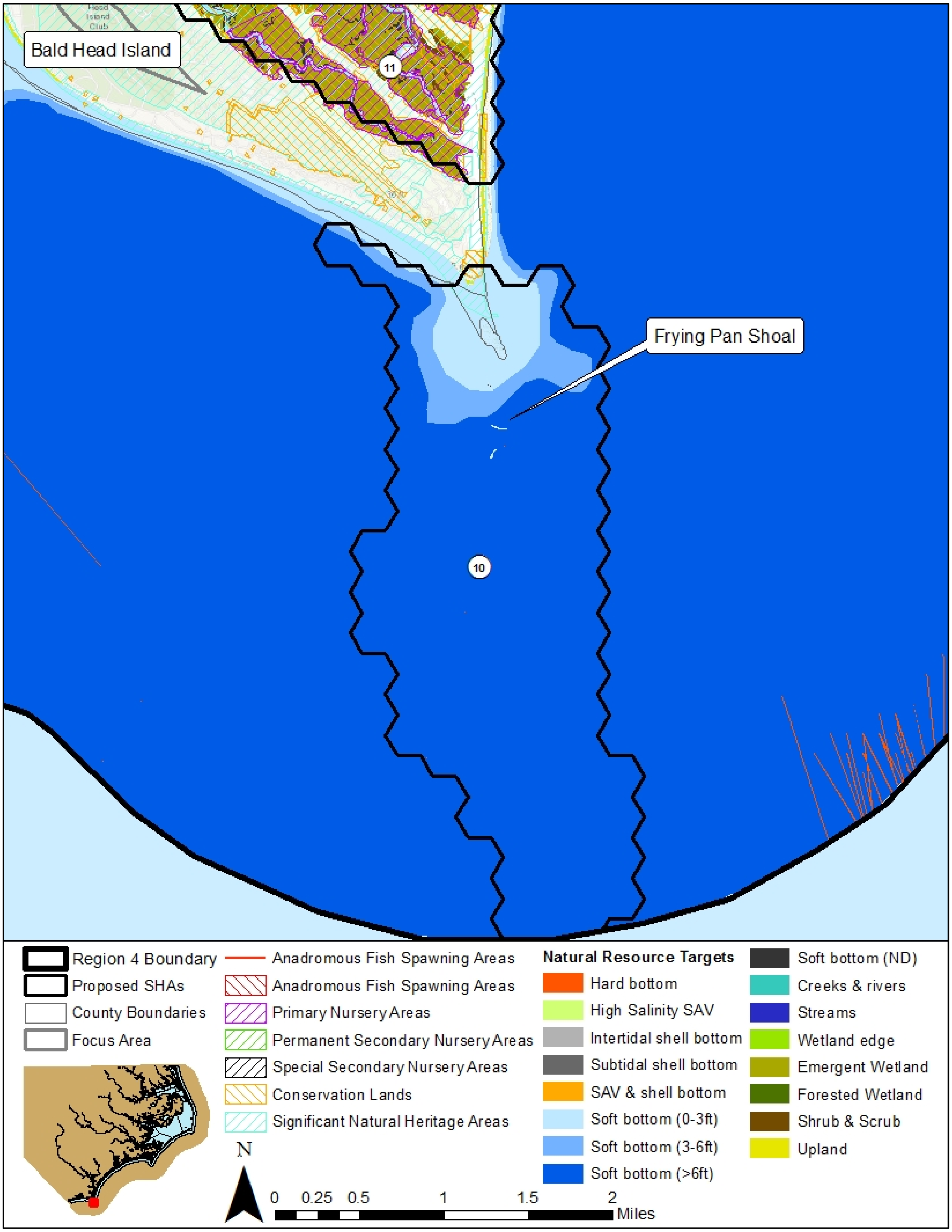
Map 13. Draft Strategic Habitat Area (SHA) nomination #5 – Lockwoods Folly River northeast of Supply.



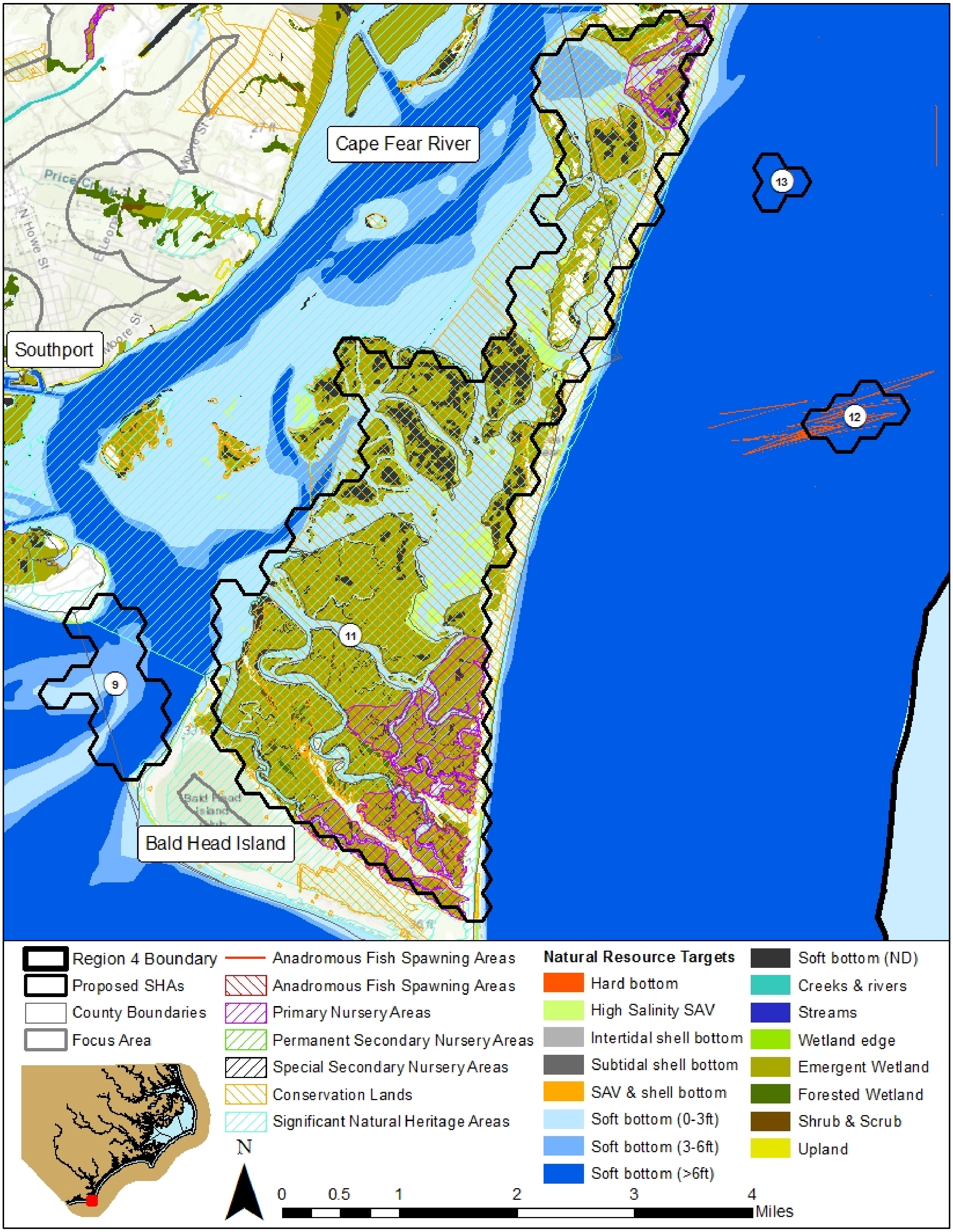
Map 14. Draft Strategic Habitat Area (SHA) nominations #6 – Artificial Reef 430, #7 – Yaupon Beach reef, Artificial Reef 425, and part of #8 – Caswell Beach.



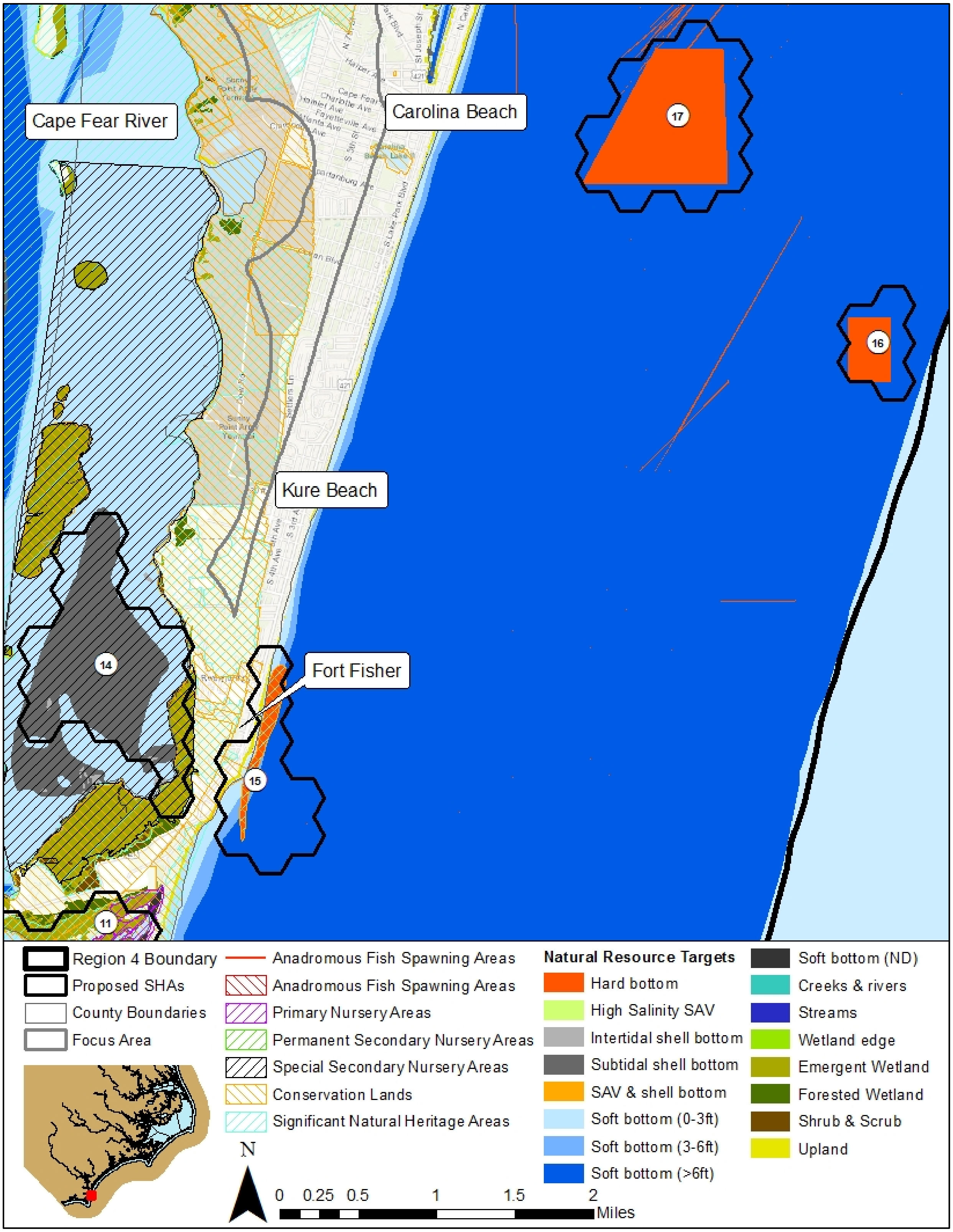
Map 15. Draft Strategic Habitat Area (SHA) nominations #8 – Caswell Beach and #9 – Cape Fear River Inlet and part of #11 – Bald Head Island.



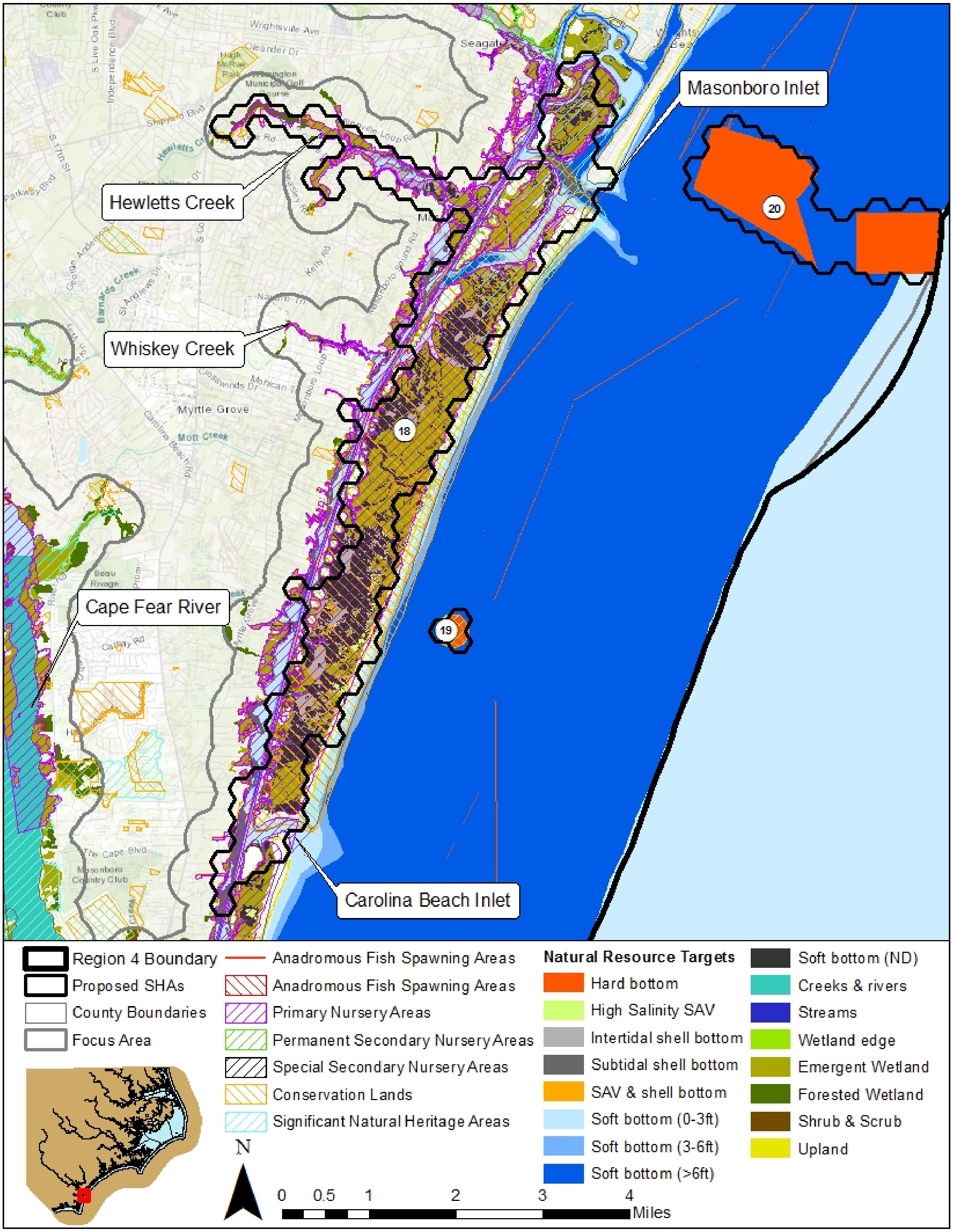
Map 16. Draft Strategic Habitat Area (SHA) nominations #10 – Frying Pan Shoal and parts of #9 – Cape Fear River Inlet and #11 – Bald Head Island.



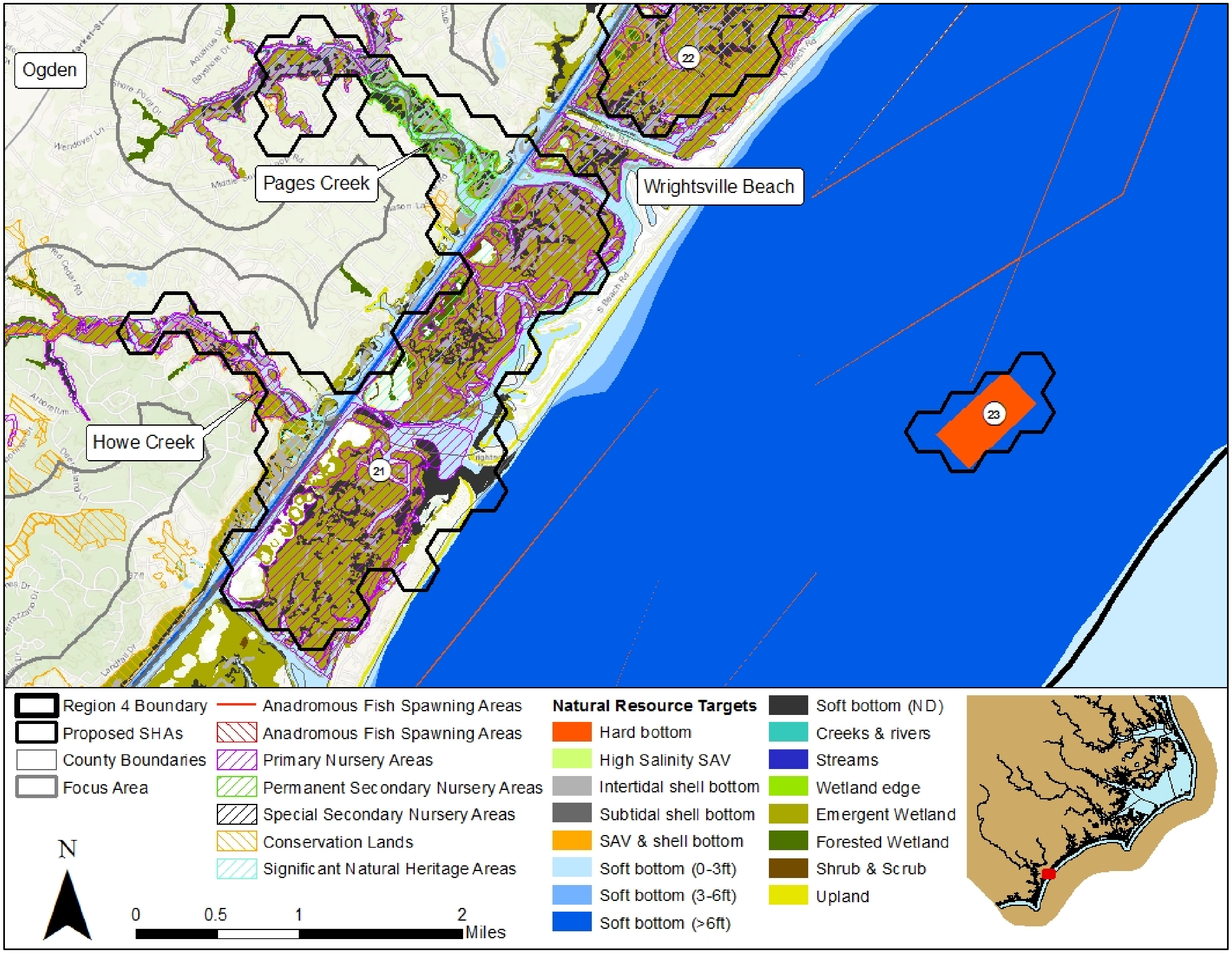
Map 17. Draft Strategic Habitat Area (SHA) nominations #9 – Cape Fear River Inlet, #11 – Bald Head Island, #12 – hard bottom off Fort Fisher, and #13 – Sheepshead Rock.



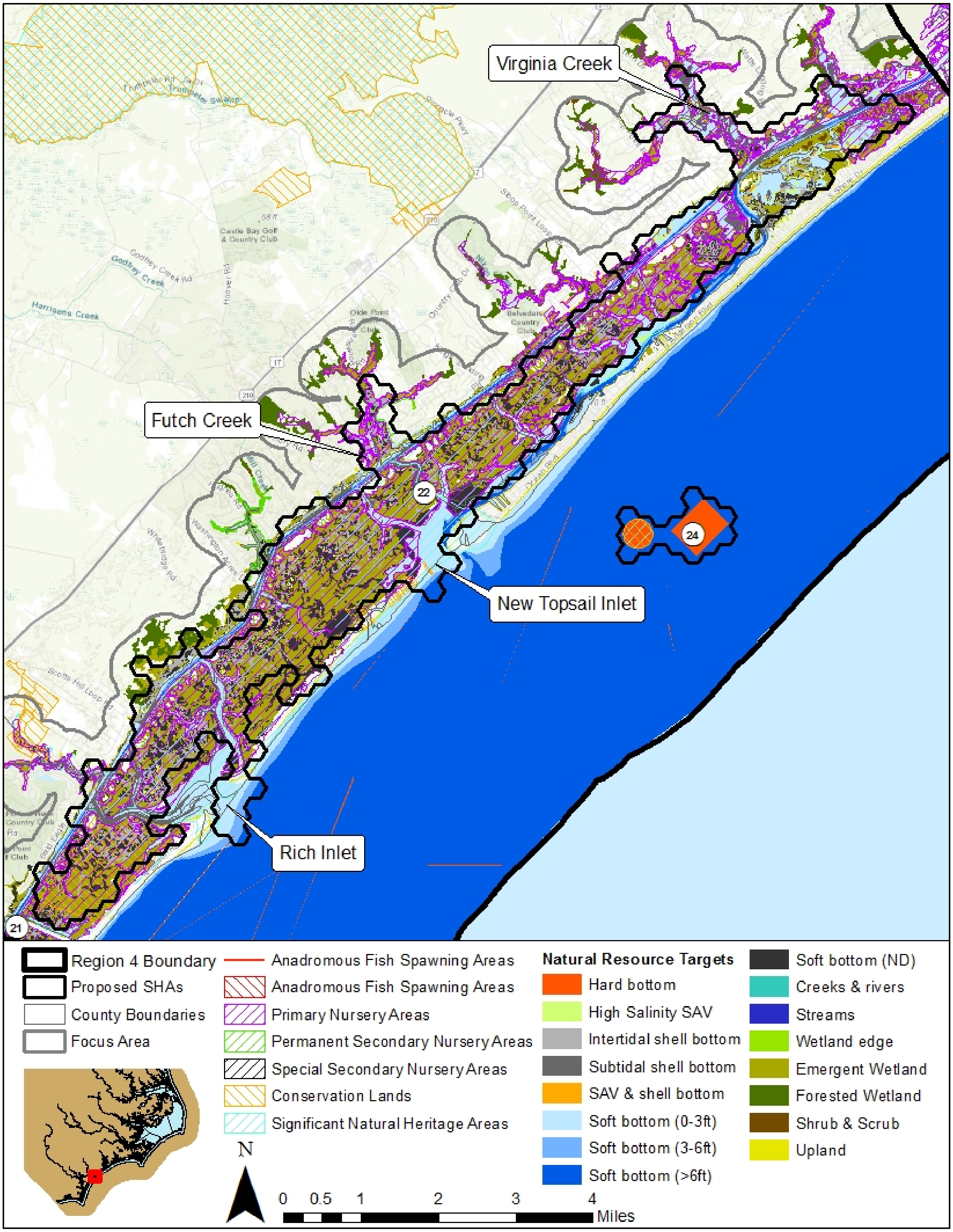
Map 18. Draft Strategic Habitat Area (SHA) nominations #14 – Cape Fear River at Sunny Point, #15 – Fort Fisher Cocquina Outcrop, #16 – Artificial Reef 378B, and #17 – Phillip Wolfe Reef, Artificial Reef 378.



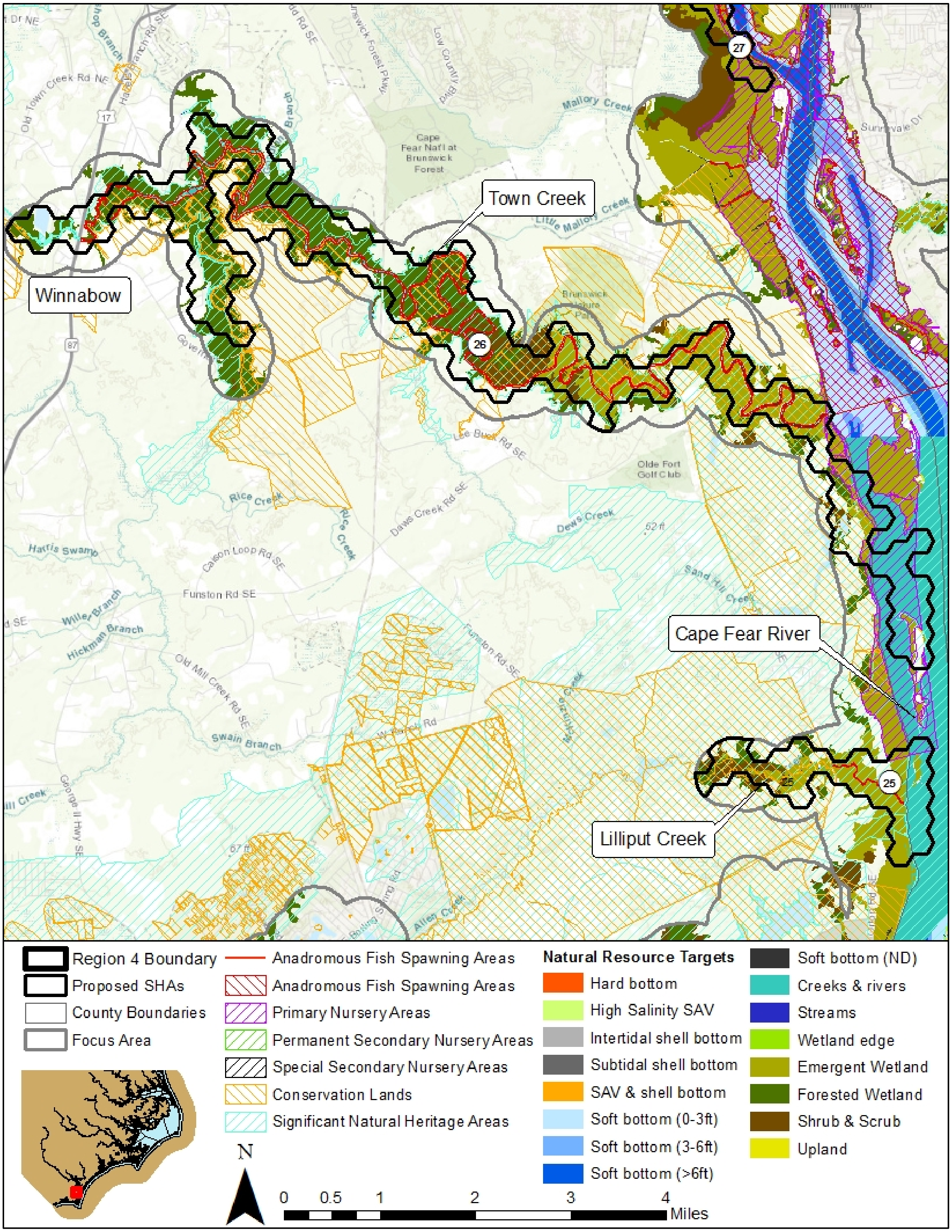
Map 19. Draft Strategic Habitat Area (SHA) nominations #18 – Masonboro Island and Whiskey and Hewletts Creek, #19 – Masonboro Outcrop, #20 – Meares Harris, Artificial Reef 370.



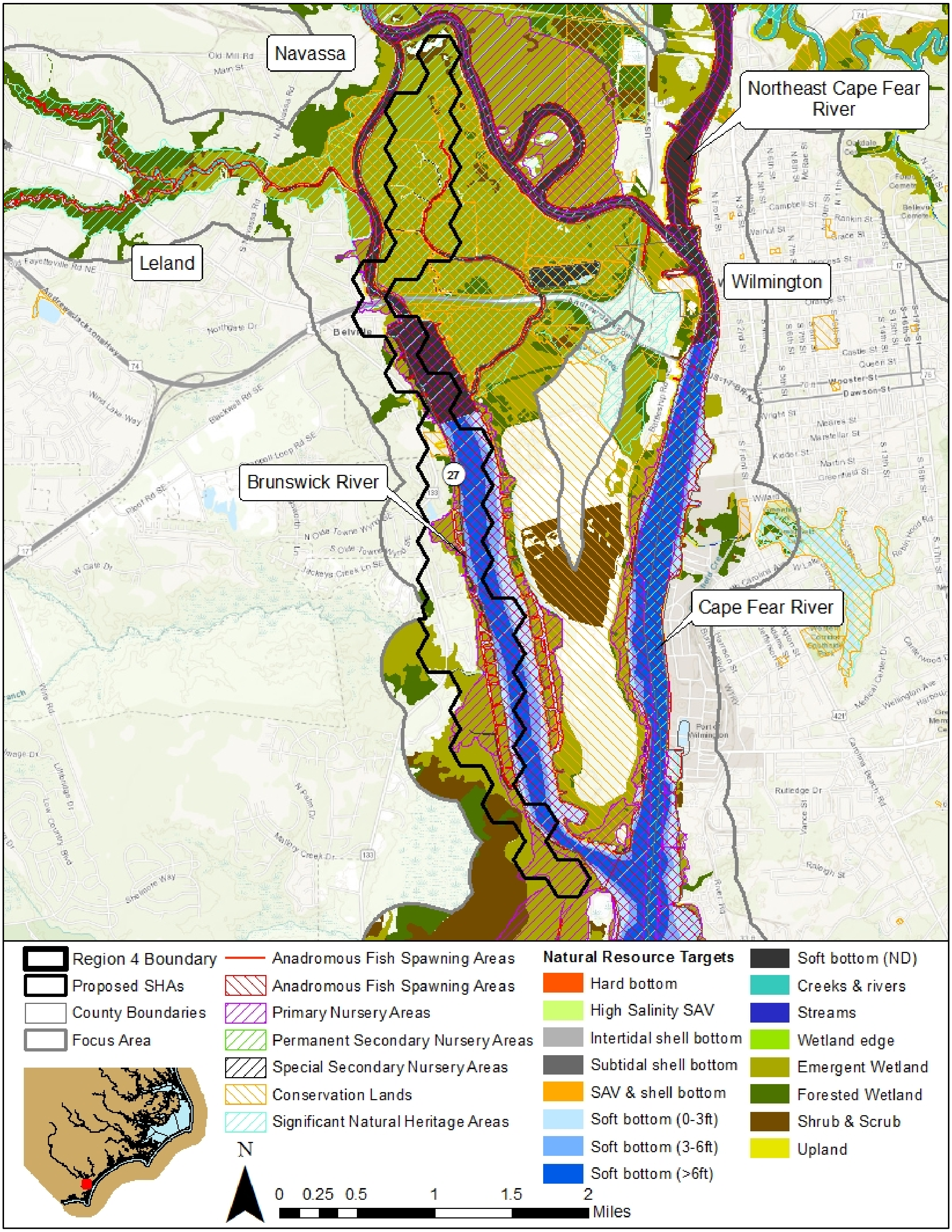
Map 20. Draft Strategic Habitat Area (SHA) nominations #21 – Wrightsville Beach including Howe and Pages creeks, #23 – Billy Murrel Reef, Artificial Reef 364, and part of #22 – Topsail Beach.



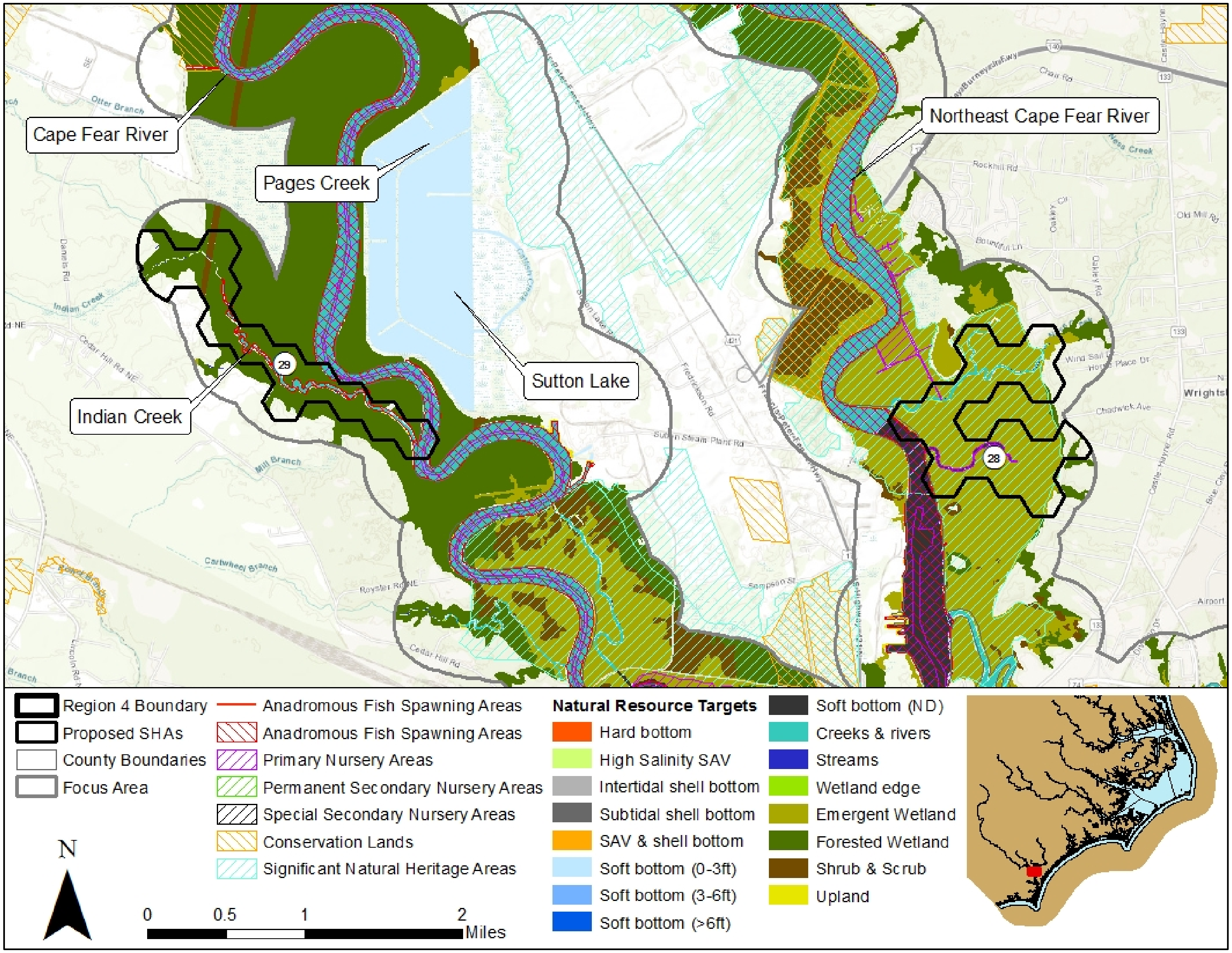
Map 21. Draft Strategic Habitat Area (SHA) nominations #22 – Topsail Beach including Futch and Virginia creeks and Rich and New Topsail inlet and #24 – Topsail Reef, Artificial Reef 360.



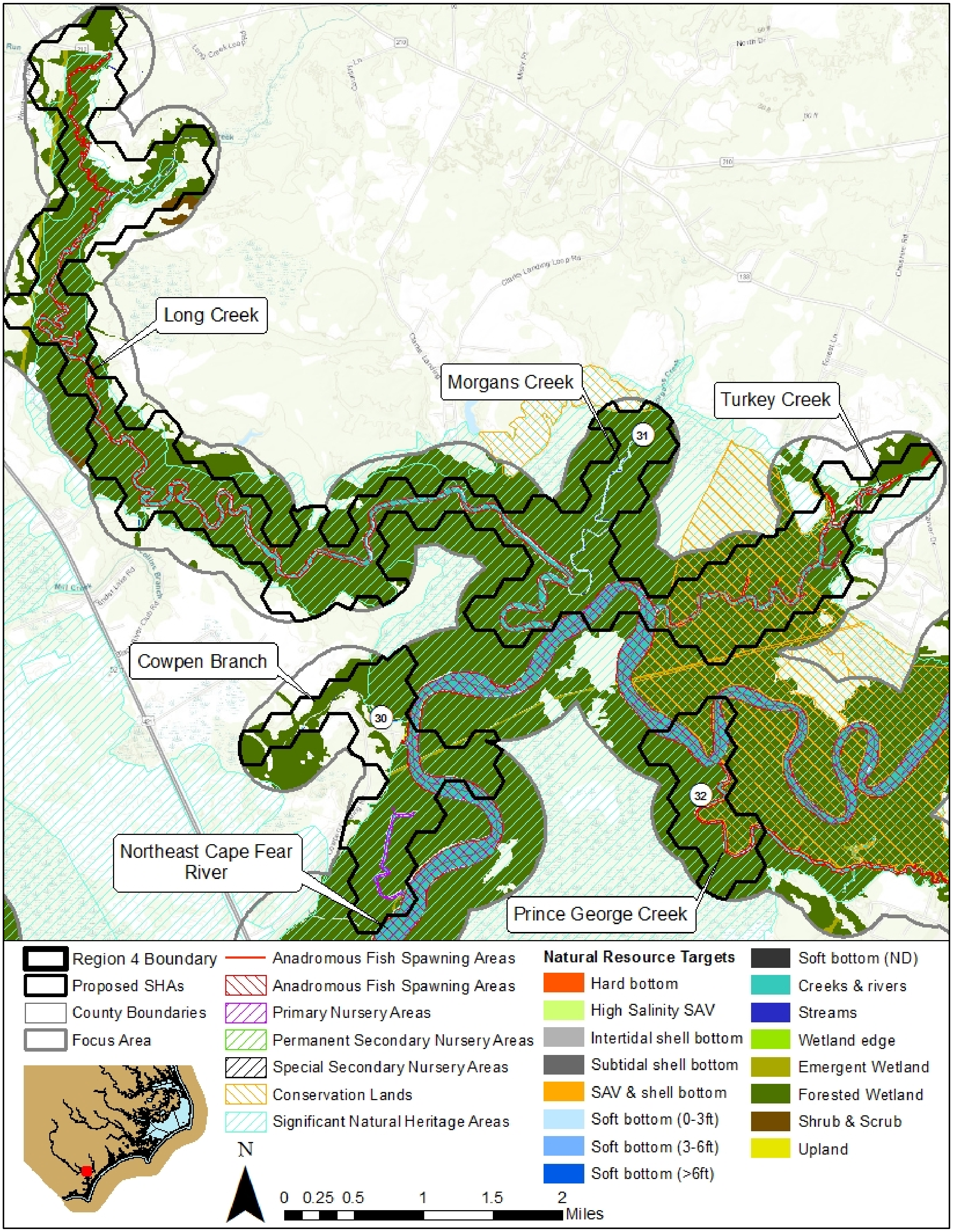
Map 22. Draft Strategic Habitat Area (SHA) nominations #25 – Cape Fear River, Lilliput Creek and #26 – Cape Fear River, Town Creek.



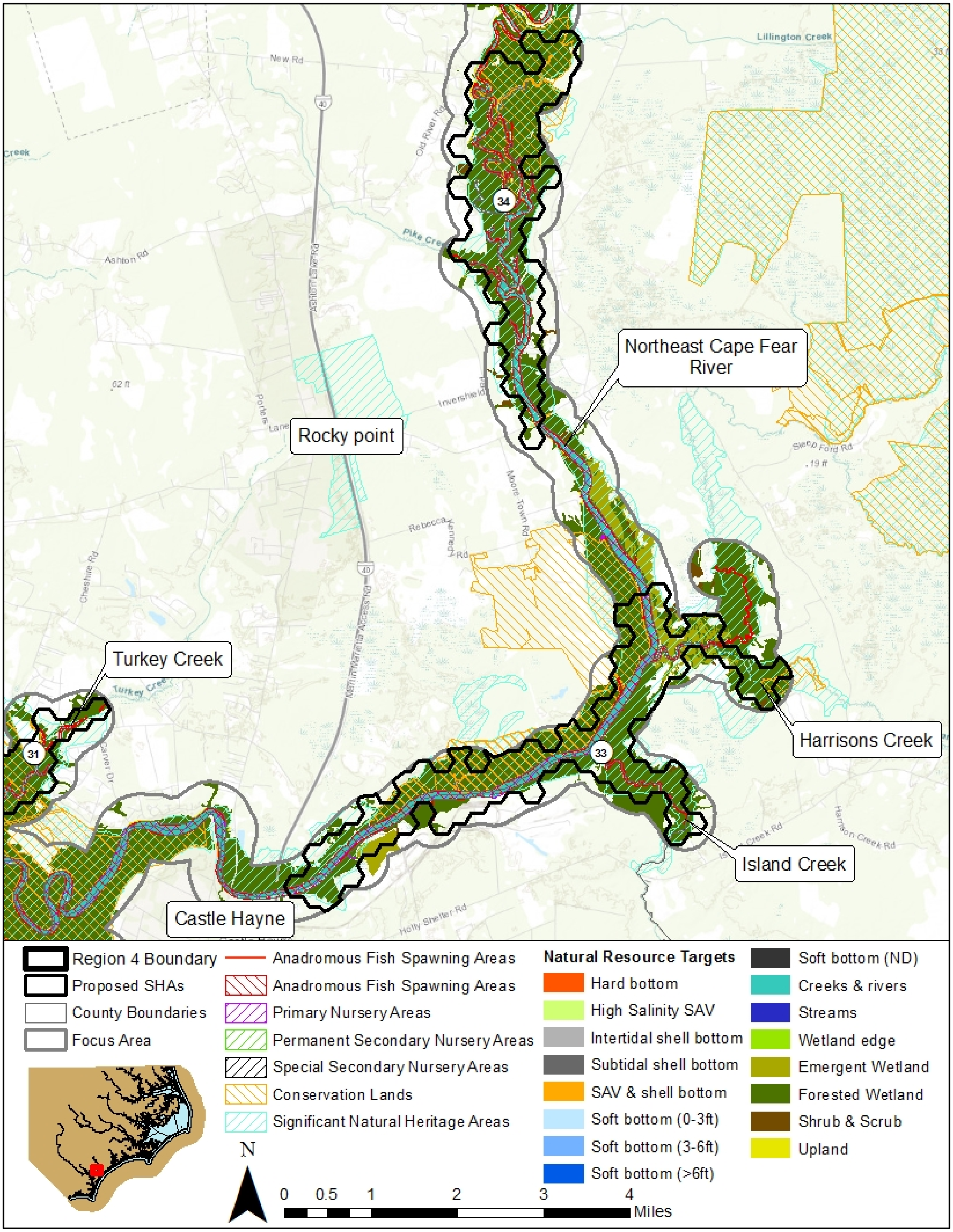
Map 23. Draft Strategic Habitat Area (SHA) nomination #27 – Brunswick River.



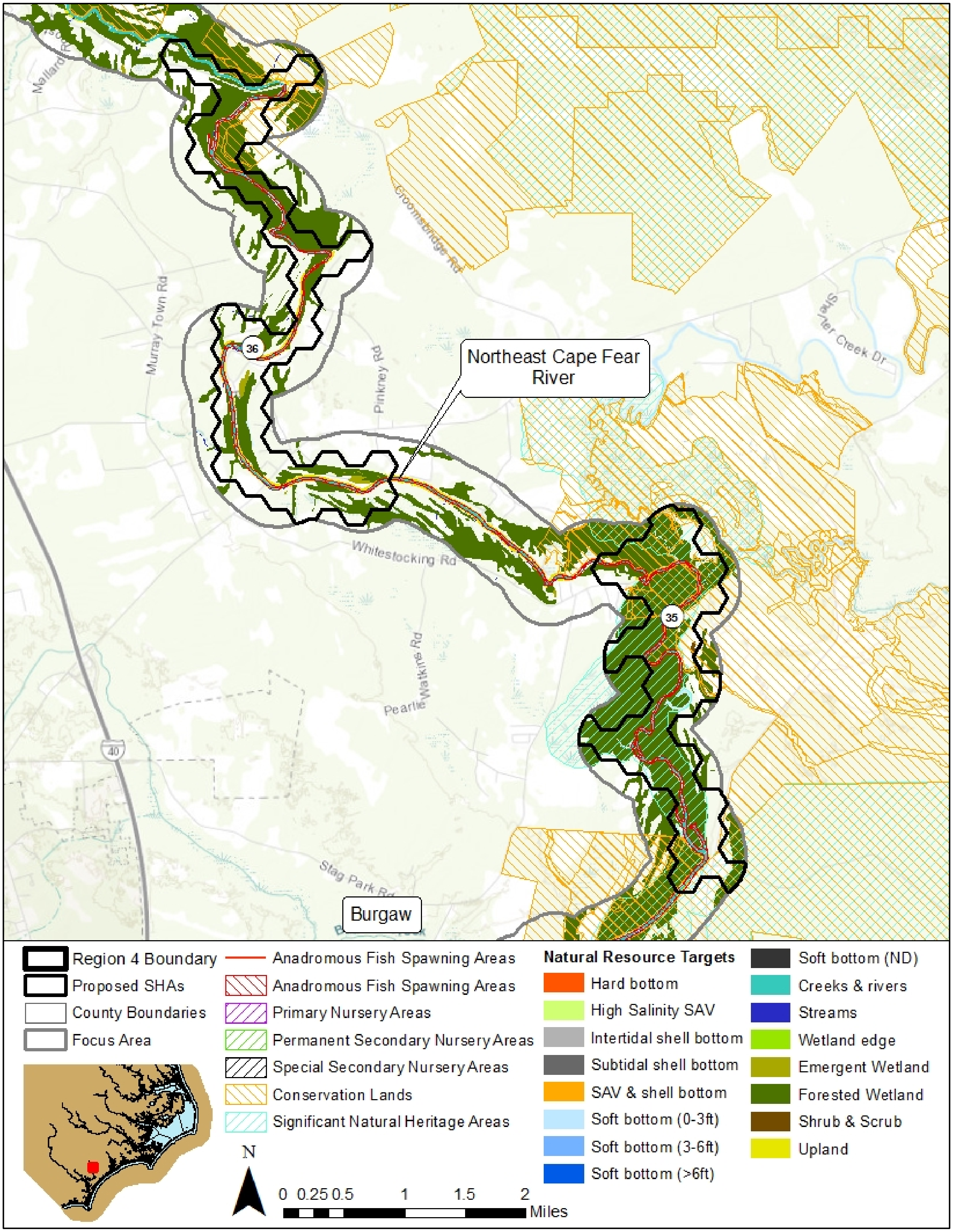
Map 24. Draft Strategic Habitat Area (SHA) nominations #28 – Northeast Cape Fear River, Ness Creek and #29 Cape Fear River, Indian Creek.



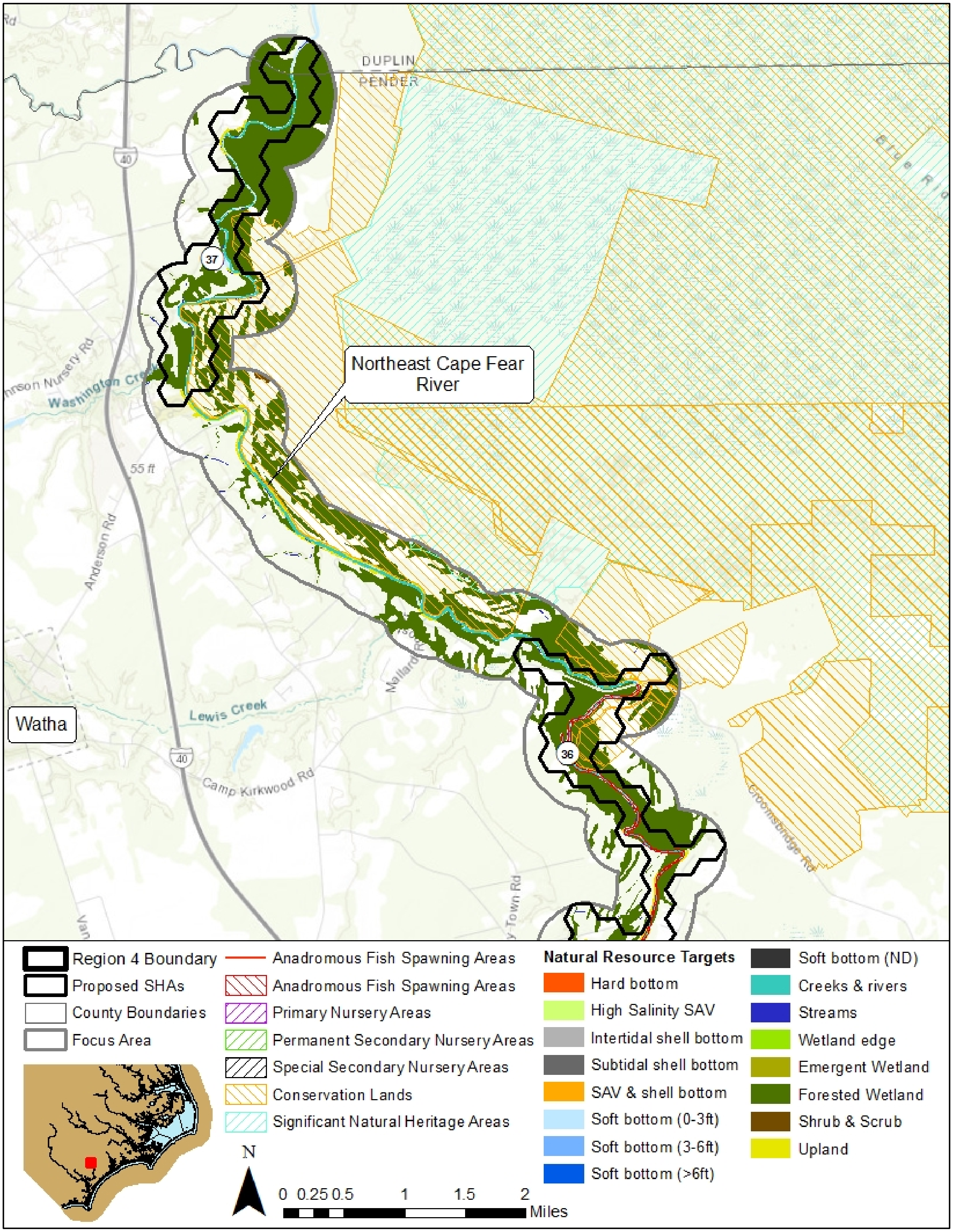
Map 25. Draft Strategic Habitat Area (SHA) nominations #30 – Northeast Cape Fear River, Cowpen Branch, #31 Northeast Cape Fear River, Long, Morgans, and Turkey creeks, and #32 – Northeast Cape Fear River – Prince George Creek.



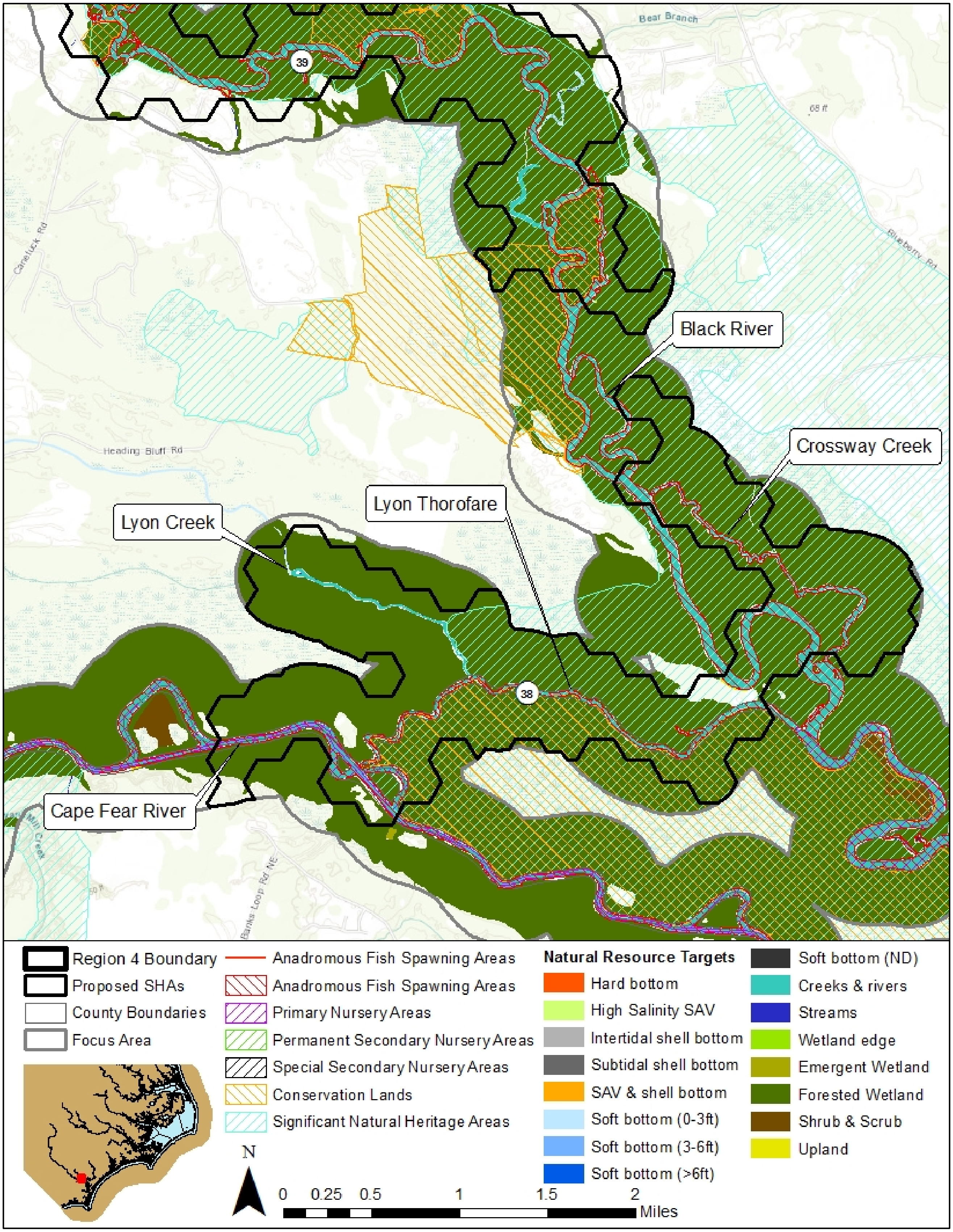
Map 26. Draft Strategic Habitat Area (SHA) nominations #33 – Northeast Cape Fear River, near Castle Hayne including Island and Harrisons creeks and #34 – Northeast Cape Fear River, near Rocky Point.



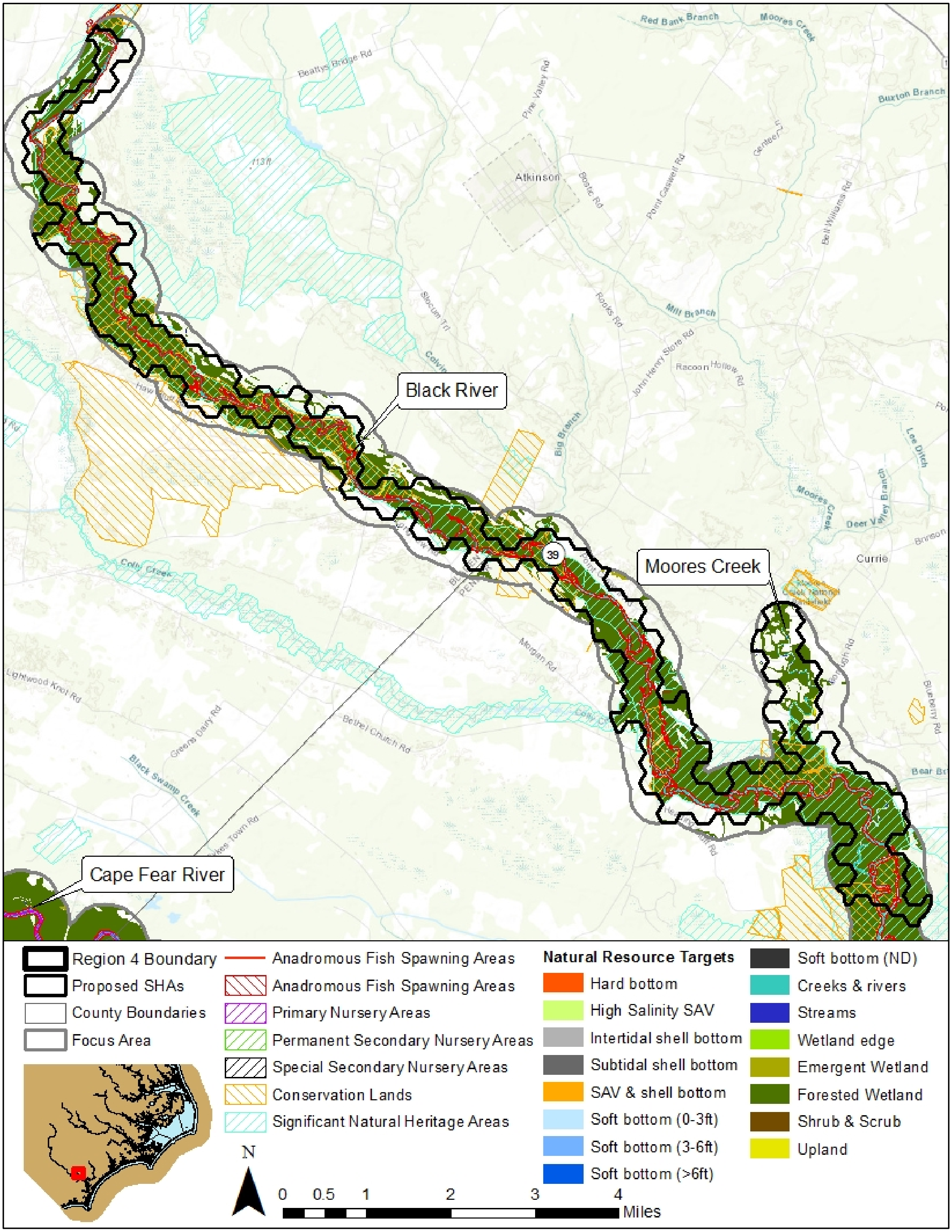
Map 27. Draft Strategic Habitat Area (SHA) nominations #35 – Northeast Cape Fear River, Ashes Creeks and #36 – Northeast Cape Fear River, Watermelon Run.



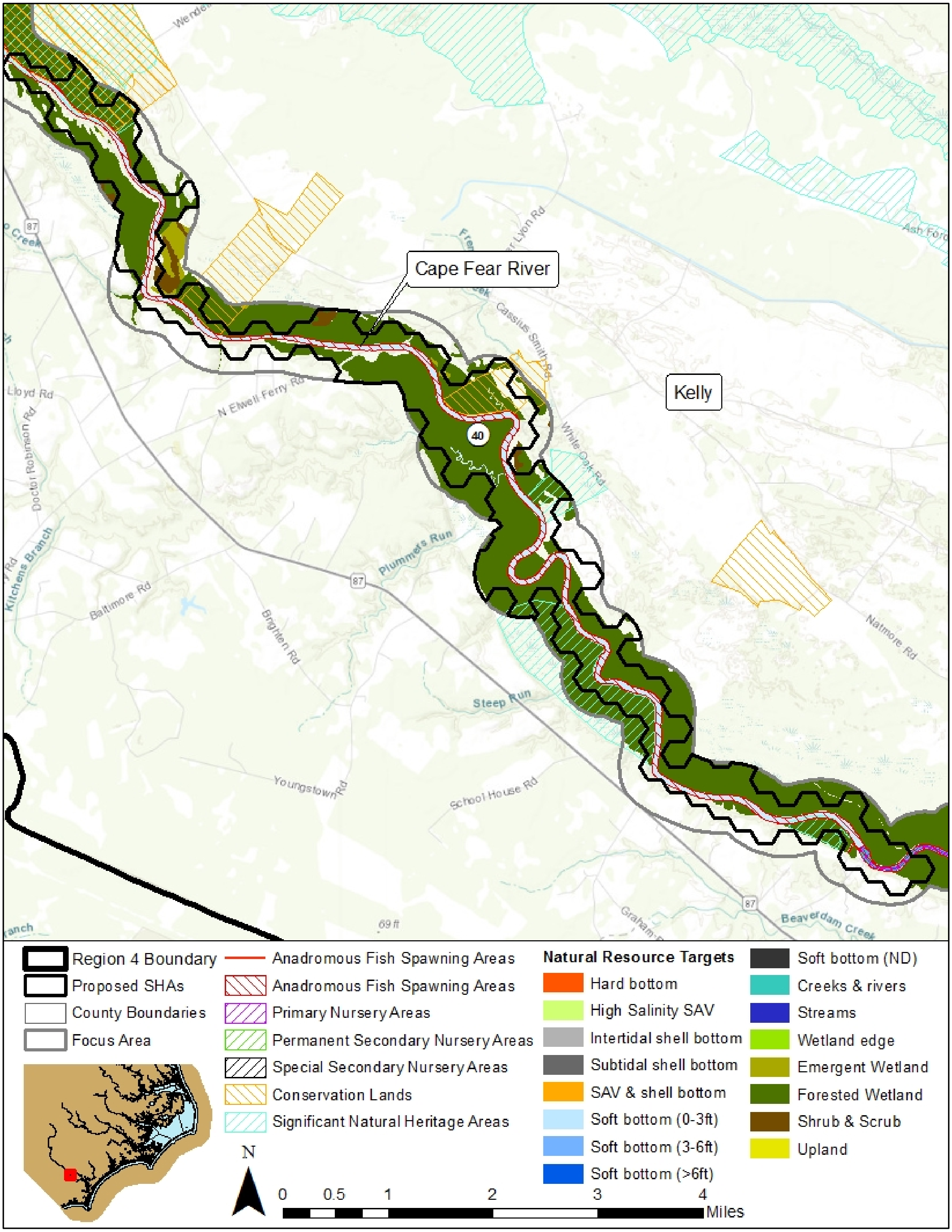
Map 28. Draft Strategic Habitat Area (SHA) nominations #37 – Northeast Cape Fear River, Duplin/Pender County line and part of #36 – Northeast Cape Fear River, Watermelon Run.



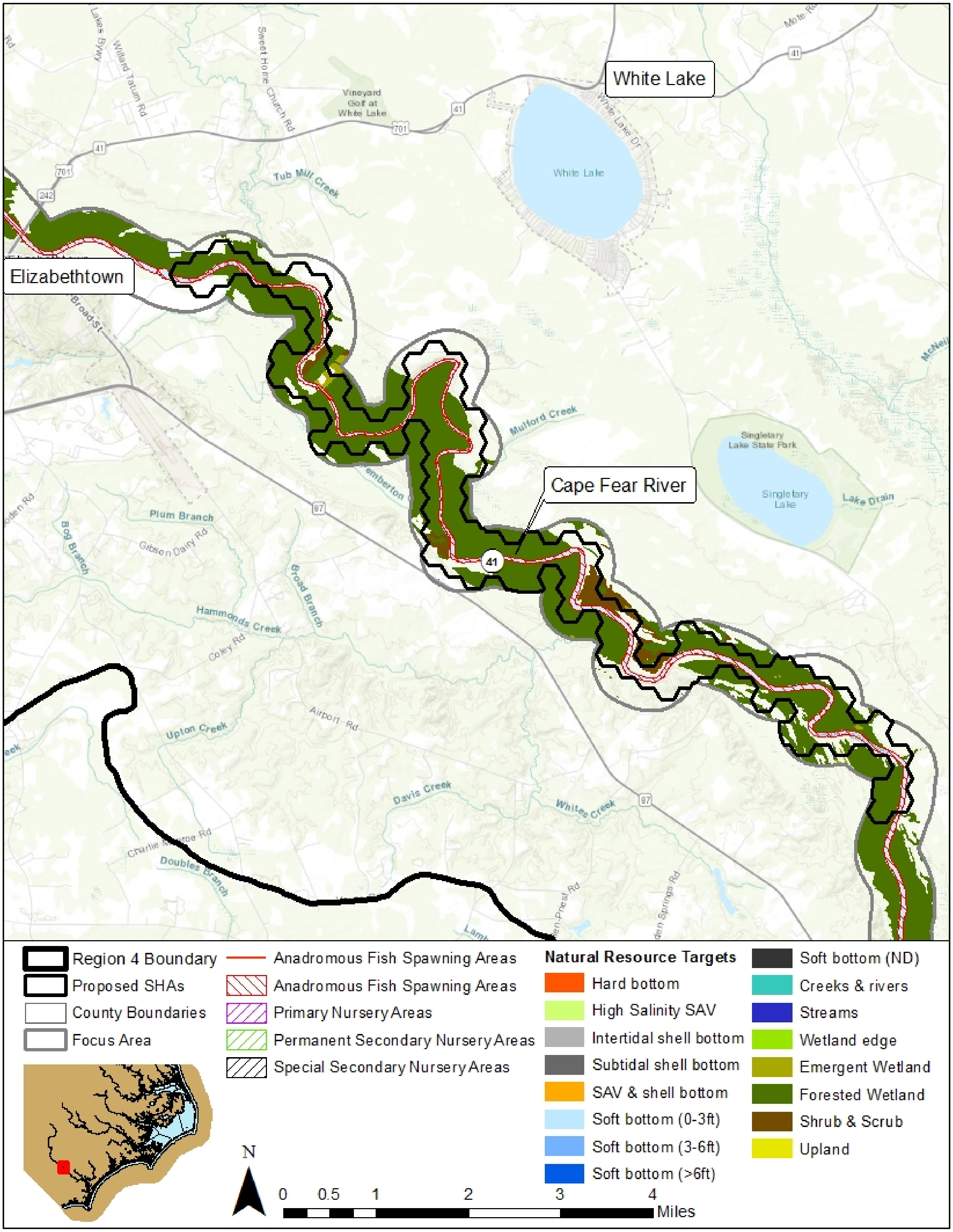
Map 29. Draft Strategic Habitat Area (SHA) nominations #38 – Cape Fear River lowlands, Lyon and Crossway creeks and Lyon Thorofare and part of #39- Black River, Moores Creek..



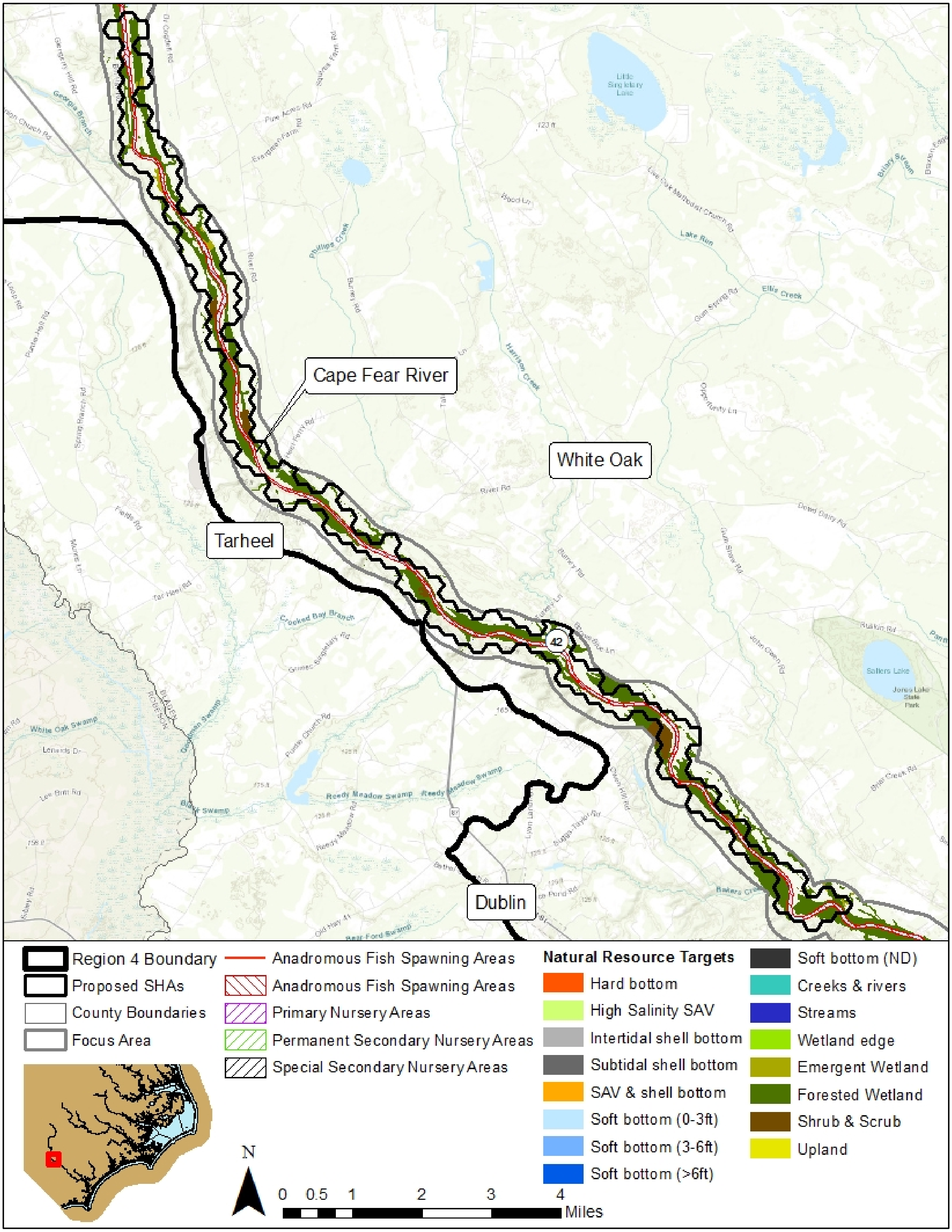
Map 30. Draft Strategic Habitat Area (SHA) nomination #39 – Black River, Moores Creek.



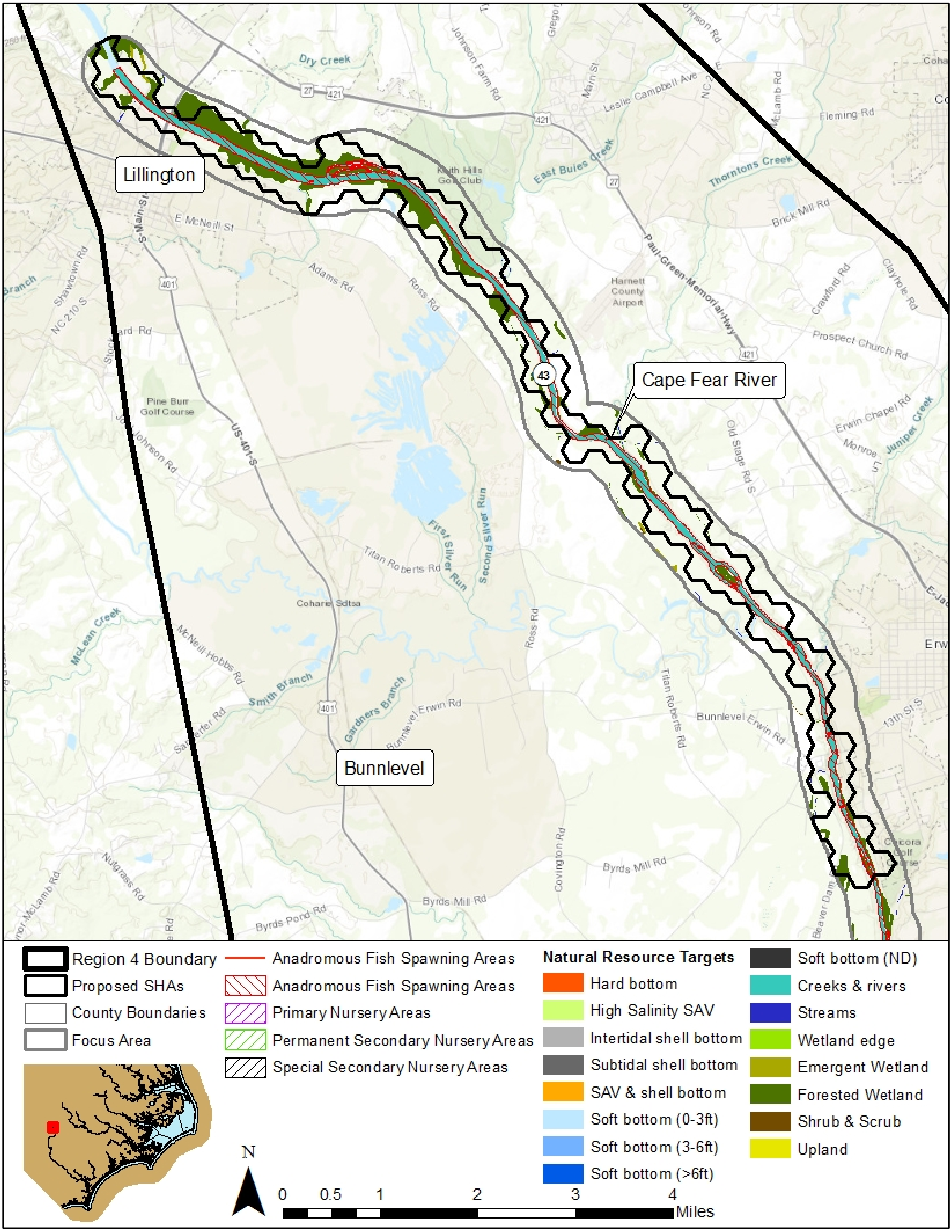
Map 31. Draft Strategic Habitat Area (SHA) nomination #40 – Cape Fear River near Kelly.



Map 32. Draft Strategic Habitat Area (SHA) nomination #41 – Cape Fear River below Elizabethtown.



Map 33. Draft Strategic Habitat Area (SHA) nomination #42 – Cape Fear River at Tarheel.



Map 34. Draft Strategic Habitat Area (SHA) nomination #43 – Cape Fear River at Lillington.

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8 APPENDIX A: NATURAL RESOURCE TARGETS AND CALCULATING TOTAL ALTERATION

Alteration scores are calculated for each hexagon and take into account the following factors:

1. **S**everity of an alteration factor/threat to each natural resource target (**S** rating).

2. **E**xtent that an alteration factor/threat affects each natural resource target (**E** rating)

3. **P**ortion of total natural resource targets in hexagon consisting of natural resource target X (**P** rating).

Severity (**S**) ratings in were based on the individual habitat ratings for each threat listed in the threats table of the Coastal Habitat Protection Plan (CHPP) (Street et al. 2005, p. 486) and approved by the Marine Fisheries Commission, Coastal Resources Commission, Environmental Management Commission, and N.C. Department of Environment and Natural Resources in 2004. This rating ranges from 0 (no impact) to 3 (high impact) and estimates the potential impact of each alteration factor on each natural resource target or habitat type in the assessment. For water-based alteration factors (i.e., trawling or dredging), the rating in the CHPP (Street et al. 2005, p. 486) was directly applied. For land-based alteration factors (i.e., developed land use or agricultural land cover), an adjusted **S** rating is applied to all hexagons within a U.S. Geological Survey-designated hydrologic unit (HU). This adjusted **S** rating scales the intensity of activity to the maximum occurring within the region. To do this, first the relative intensity of the alteration is computed for each HU within the region by dividing by the maximum value occurring in the region. These values are then multiplied by the severity ratings given in Table 3 of the main report to get the adjusted severity for each particular alteration factor and habitat combination in each hexagon.

An example is shown in Table A.1. For example, if the severity rating for agricultural land use on the submerged aquatic vegetation (SAV) natural resource target or habitat type is 2, and the hexagon lies within an HU with 40% cropland coverage and the maximum percent cover in the study area is 50% (resulting in an alteration intensity of 0.8), the resulting **S** rating for that hexagon would be 2 x 0.80 or 1.60 (Table A.1).

Table A.1. Example calculation of the adjusted **S** (severity) value for land-based factors.

HU	Hexagon	% Agricultural Land Use	Scaled Intensity	Adjusted S
1	A	0	0	2 x 0 or 0
1	B	0	0	2 x 0 or 0
1	C	0	0	2 x 0 or 0
2	D	40	0.8	2 x 0.8 or 1.60
3	E	50 (maximum)	1.0	2 x 1.0 or 2.0
3	F	50 (maximum)	1.0	2 x 1.0 or 2.0

Extent (**E**) ratings were determined by calculating the percent of the habitat within the hexagon that is affected by the factor. For water-based factors (i.e. dredging), the threat may only overlap with a portion of the habitat present. For land-based alteration factors calculated at the HU level, the **E** rating is simply 1 (complete overlap) for hexagons fully within a hydrologic unit.

Portion (**P**) ratings are calculated as the number of acres for a particular natural resource targets divided by the total acres for all natural resource targets present within the hexagon of interest.

The total alteration of each habitat in a hexagon with one alteration factor is determined by multiplying S, E and P ratings: **Habitat X weight rating = S x E x P** (Figure **B-1**).

For example: a hexagon has one alteration factor – dredged channels, and contains 21 acres (70%) soft bottom and 9 acres of SAV (Figure A.1, Table A.2). Within the 9 acres of SAV, trawling is allowed over 0% (E=0.0). The S rating of dredging on SAV is 2 (moderate) and the portion of SAV among targets in the hexagon is 30% or 0.3. The final rating for SAV would be S (2) x E (0.0) x P (0.7) = 0.0. Within the 21 acres of soft bottom, dredging is allowed over 20% (E = 0.2). The portion (P) of the soft bottom among targets in the hexagon is 70% or 0.7. The S rating for dredging on soft bottom is 1. The final rating for soft bottom is S(1) x E(0.2) x P(0.7) = 0.14. The total alteration of the hexagon would be 0.14 (0.00 + 0.14).

Figure A-1. Diagram depicting how alteration weightings are applied within a hexagon containing multiple targets. Hexagon A contains 70% soft bottom, 30% SAV, and a dredged channel through soft bottom.

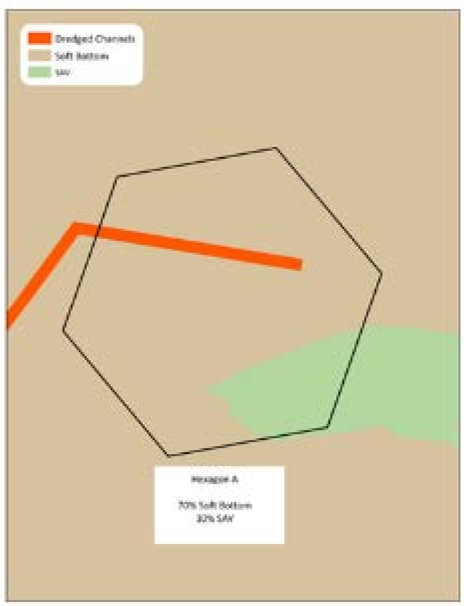

Table A.2. Calculation of hexagon alteration with only one alteration factor, but which occurs in some portion of two habitat types. S=severity, E=extent, P=portion

Hexagon	Natural Resource Target	Total area (acres)	$S^{dredging}$	$E^{dredging}$	P	SxExP	Total Weight
Hexagon A	SAV	9	2	0.0	0.30	0.00	0.14
	Soft Bottom	21	1	0.2	0.70	0.14	

When more than one alteration factor is present within a hexagon, the weight for each habitat (all factors) is determined by summing the S x E of each factor and multiplying by the percent of that habitat comprising the targets (P). The habitat alterations are summed to obtain one total alteration value for each cell (Table **A.3**).

Table A.3. Example of calculations to determine total alteration level of one hexagon with multiple alterations and habitats occur.

Factors		S x E			
		Shallow Soft Bottom	Soft Bottom (ND)	Wetland	Upland
HU-based Alterations (land-based alterations)	Animal Operations	0	0	0	0
	Shellfish Closures	0.73	0.02	0	0
	Major NPDES	0	0	0	0
	Minor NPDES	0	0	0	0
	Agricultural Land Use	0.06	0.06	0.06	0.06
	Developed Land Use	0.54	0.54	0.54	0.54
Area-based Alterations (water-based alterations)	Drained	0	0	2	0
	Canals and Boat Basins	1	0.23	0	0
	Bridge Constrictions	0	0	0	0
	Impounded	0	0	0	0
	Docks & Bridges	0	0	0	0
	Dredged	0	0	0	0
	Marinas	1.45	0.041	0	0
	Clam Harvest	0	0	0	0
	Trawl Opened	0	0	0	0
	Bulkhead	0	0	0	0
	Culvert	0	0	0	0
	Riprap	0	0	0	0
SUM		3.78	0.891	2.603	0.603
Fraction of Targets (P)		156.59 (0.07)	464.99 (0.21)	99.02 (0.045)	1495.81 (0.6748)
Sum x P		0.26	0.187	0.117	0.407
Total Alteration Score For Hexagon A					0.97

8.1 Processing Details

For the Region 4 analysis, the alteration calculations were completed using a combination of ArcGIS tools and R scripts. This approach was useful because it allowed the alteration scores to be quickly recalculated as changes were made throughout the SHA process. While the processing models and scripts are currently specific to the data found in this region, they could easily be adapted for the analyses in the following regions.

The process began by building a geodatabase of alteration data layers. Some manipulation was required to create the input layers for the alteration score. Tools were created using ArcGIS

ModelBuilder with ArcGIS version 10.3. ModelBuilder allows the user to combine multiple tools and then execute them as a single process. The benefit to this approach was that it made the process transparent and easy to repeat.

The first step in creating the alteration score is to create the alterations habitat dataset. This is stored in the field ALT_HABITA in the following steps. Below is a table showing the relationship between NRT types for Region 4 and the habitat types for alteration.

Table A.4. Habitat categories used to apply unique alteration ratings.

Natural Resource Targets	Alteration Habitat Type	GIS Layer Type	Notes
Hard Bottom	Hard Bottom	Polygon	Selected post-analysis by SHA AC.
High Salinity SAV	SAV	Polygon	
Low Salinity SAV			None within Region 4
Intertidal Shell Bottom	Shell Bottom	Polygon	
Subtidal Shell Bottom			
SAV & Shell Bottom	SAV & Shell Bottom	Polygon	
Riverine Soft Bottom (0-3ft)	Creeks and Rivers	Polygon	
Riverine Soft Bottom (3-6ft)			
Riverine Soft Bottom (ND)			
Estuarine Soft Bottom (0-3ft)	Shallow Soft Bottom	Polygon	
Palustrine Soft Bottom (0-3ft)			
Marine Soft Bottom (0-3ft)			
Estuarine Soft Bottom (3-6ft)			
Palustrine Soft Bottom (3-6ft)			
Marine Soft Bottom (3-6ft)			
Estuarine Soft Bottom (>6ft)			
Marine Soft Bottom (>6ft)			
Marine Soft Bottom (ND)	Deep Soft Bottom	Polygon	
Estuarine Soft Bottom (ND)			
Palustrine Soft Bottom (ND)	Soft Bottom (ND)	Polygon	
Emergent Wetlands			
Forested Wetlands			
Scrub/Shrub Wetlands			
Low Elevation Uplands	Wetlands	Polygon	
Streams (low elevation)			
Wetland Shoreline/Edge	Uplands	Polygon	
	Streams	Polygon	
	Wetland Edge	Polygon	

It is assumed that a dataset of NRT habitat types has the ALT_HABITA field populated before the alteration score calculations can begin. Begin by dissolving the Natural Resource Target data layers by the ALT_HABITA field to get a feature class of alteration habitats. The following describes the tools provided in the alterations toolbox. It is divided into three toolsets, which are numbered and in all caps below. Tool names are in bold, under the corresponding toolset.

8.2 Data Processing

These are miscellaneous tools that were used to create some of the inputs to alteration factors. They can be reused if needed but are provided more for convenience.

8.2.1 Aggregate point features by HU

Assigns the frequency of a point feature to the corresponding hydrologic unit in a polygon feature class of hydrologic units. Needs a HU feature class and the point feature to aggregate. This tool allows the user to choose the field or fields to aggregate. The output file contains the frequency of these fields and is named to match the names of the input fields the tool aggregates.

8.2.2 Aggregate marinas by HU

Counts the number of slips at marinas in each hydrologic unit and joins the result to a shapefile of hydrologic units. A marina is defined as a facility with greater than 10 slips.

8.2.3 Calculate marinas per shoreline

Calculates the 'marinas per shoreline metric' by calculating the number of slips per linear unit of shoreline for each hydrologic unit and joining it to the hydrologic unit feature class. This tool uses the results of the previous tool (Aggregate marinas by HU) as inputs. The output has the number of slips per meter of shoreline in a HU in the field 'slips_per_m'.

8.3 Extent Calculations

These tools generate the extent files needed as the inputs for the R scripts. Outputs are saved as DBF tables and currently written to a folder called 'data'. Field maps are given below for all of the output tables. Currently, they are organized by the aspect of habitat they affect; therefore, there is a separate tool for land-based alterations, physical conversions, and water-based alterations. This was done for Regions 3 and 4 because in Region 2, it was thought that the alteration scores were calculated the same way for each group of alterations. This ended up not being true. In future versions, it might make sense to rearrange these into linear and polygon extent calculations for the purposes of the alteration score calculation.

8.3.1 Land-based Extent (Hydrologic Unit-based Alteration Assessment)

This tool takes the land-based alterations that need to be joined to a hydrologic unit file for the purpose of analysis and creates a master table of alterations by hydrologic unit. The alteration factors that are assessed at the hydrologic unit level are (1) minor national pollutant discharge elimination systems, (2) animal operations, (3) agricultural land use, and (4) developed land use. The tool also creates a table giving the amount of each hydrologic unit in each hexagon; which is used to calculate the land-based alteration scores for hexagons that cross hydrologic unit boundaries.

INPUTS:

1. Each land-based alteration factor of interest, aggregated by the hydrologic unit. All of these are polygon feature classes.
2. Alteration habitats feature class
3. Hexagon boundaries, with a unique ID
4. Hydrologic unit boundaries with a unique ID

OUTPUTS:

1. **hu_alt_factors20170612.csv**: gives the amount of each alteration factor present by hydrologic unit

Field Name	**Description**
HU_12	USGS 12-digit hydrologic unit code.
hu_area	Area of hydrologic unit measures in square meters.
maj_NPDES	Number of major NPDES sites per hydrologic unit.
min_NPDES	Number of minor NPDES sites per hydrologic unit.
Cat_Swine_anops	Number of cattle and swine operations per hydrologic unit.
Poultry_anops	Number of poultry operations per hydrologic unit.
ag_use	Relativized proportion of agricultural land use per hydrologic unit.
dev_use	Relativized proportion of developed land per hydrologic unit.

2. **hu_by_hex20170612.csv:** calculates the areas of each hydrologic unit present within a given hexagon assessment unit (for all hexagon assessment units) and the max area of the hydrologic unit in each hexagon assessment unit. This is used to calculate scores for hexagons that cross hydrologic unit boundaries.

Field Name	**Description**
Unique_ID	Hexagon assessment unit unique identifier.
HU_12	USGS 12-digit hydrologic unit code.
hu_area	Total area of hydrologic unit measured in square meters.
hex_area	Area of hydrologic unit within each hexagon unit measured in square
MAX_HEX_AR	The maximum area of a given hydrologic unit within a single hexagon

3. **shellfish_by_hex20170612.dbf:** gives the area of each hexagon that is comprised of closed shellfish waters and the habitats that the closed areas intersect.

Field Name	Description
Unique_ID	Hexagon assessment unit unique identifier.
ALT_HABITA	Habitat type affected by alteration.
shell_area	Area, measured in square meters, of closed shellfish areas that intersect each

8.3.2 Water-based extent

This tool creates the habitat per hexagon and lines per hexagon tables that are used in all of the following R scripts.

INPUTS:

1. Polygon feature classes of the areas affected by water-based alteration factors:
    a. Drained wetland areas
    b. Dredged areas
    c. Impounded areas
    d. Canals and boat basins
    e. Bridge constrictions
    f. Docks and bridges
    g. Trawling
    h. Marinas assessed by shellfish growing areas (SGAs)
    i. Clam harvesting areas
    j. Seawalls
    k. Riprap
    l. Ditched areas
    m. Culvert obstructed areas
    n. Shellfish closures
2. Alteration habitats polygon feature classes
3. Hexagon assessment unit feature class

OUTPUTS:

1. **hab_alt_by_hex20170612.csv** - Each line represents a unique combination of hexagon assessment unit, habitat type, and alteration factor type. The output is a table that gives presence (1) or absence (0) of each alteration factor for each area described in the table. The field alt_area gives the area of each overlapping feature.

Field Name	Description
ALT_HABITA	Habitat type for alteration.
canal_bb	Identifies the alteration present. One (1) for presence and zero (0) for absence.
brdge_cons	
impounded	
docks_br	
dredged	
drained	
mar_SGA	
clam_harv	
culverts	
trawl_perm	
Unique_ID	Hexagon assessment unit unique identifier.

alt_area	Area of alteration factor and habitat overlap, measured in square meters.

2. **lines_by_hex_table20170612.csv** – gives a list of the linear feature types (wetland shoreline/edge, streams) found in each hexagon and the length of each feature within the hexagon, measured in meters.

Field Name	**Description**
Unique_ID	Hexagon assessment unit unique identifier.
ALT_HABITA	Linear habitat type for alteration.
length_new	Length, measured in meters, of each habitat type within each hexagon

3. **lines_by_ditch_by_hex20170612.csv –** Gives the proportion of linear habitat affected by ditching in each hexagon.

Field Name	**Description**
Unique_ID	Hexagon assessment unit unique identifier.
ALT_HABITA	Habitat type for alteration (linear features)
length_new	Length of habitat within hexagon unit, in meters.
ditched	Presence (1) or absence (0) of ditching.
ditch_le	Length of ditched segments, measured in meters.
prop_ditch	Proportion of habitat type, per hexagon, that is affected by ditching.

4. **seawalls_by_hex20170612.csv –** Gives the amount of seawalls in each hexagon.

Field Name	**Description**
ALT_HABITA	Linear alteration type.
Unique_ID	Hexagon assessment unit unique identifier.
wall_len	Length of the bulkhead (seawall), in meters.

5. **riprap_by_hex20170612.csv –** Gives the length of riprap in each hexagon and its associated linear habitat type affected.

Field Name	Description
Unique_ID	Hexagon assessment unit unique identifier.
ALT_HABITA	Linear habitat type.
riprap_le	Length of riprap affecting habitat within each hexagon, measured in

6. **streams_by_culvert_by_hex20170612.csv –** Gives the total length of streams within hexagons affected by culverts.

Field Name	**Description**
Unique_ID	Hexagon assessment unit unique identifier.
ALT_HABITA	Habitat type for alteration (only stream habitat type).

strm_leng	Length of stream habitat type per hexagon, measured in meters.

7. **shoreline_by_hex20170612.csv –** lists the shorelines found in each hexagon

Field Name	Description
ALT_HABITA	Linear alteration shoreline habitat type (wetland edge or non-wetland
Unique_ID	Hexagon assessment unit unique identifier.
shoreline	Length of shoreline in hexagon assessment unit, in meters.

8. **hab_by_hex20170612.csv –** Gives a table of habitat types and area (in square meters) within each hexagon assessment unit.

Field Name	Description
ALT_HABITA	Habitat type for alteration.
Unique_ID	Hexagon assessment unit unique identifier.
hab_area	Area of each habitat type within hexagon assessment unit.

8.3.3 R Tools for use in calculating alterations

These tools take the outputs of the previous steps (the steps performed in ArcGIS) and use them to combine the severity, extent, and portion into a complete alteration score for each hexagon. There are three separate scripts to calculate the severity by extent ratings: one each for the physical, water-based, and land-based alteration groups. The outputs from these scripts are then combined into the total alteration score in one final script (alteration scores.r). Input and output file locations are in the top portions of all scripts and can be easily changed to match where the data is stored. All scripts require a csv file of the severity ratings in order to calculate the severities for each alteration/habitat combination in each hexagon. This file gives the severity (0-3) for each alteration/habitat combination. Alterations and habitats that do not overlap are assigned a value of 0 for the purpose of calculating the scores. Column names are alteration factors and row names are alteration habitat types.

Names are case sensitive and must match those that are in the output tables from the Arc scripts. Columns do not have to be in any particular order; the scripts will select the correct ones.

Each script file has two sections: a top section labeled “INPUTS” and a lower portion labeled “CALCULATIONS. In order to use these for different files, it will be necessary to open them and change the directories listed under the inputs section to match the correct file locations. The working directory needs to be set to the alteration folder. All files except for the csv of habitat severities are outputs of the ArcGIS tools described in the previous sections. Each input section contains a list of the alterations included in each script. In order to add other alterations in future analyses, these lists would need to be amended with the field names of the new alterations. Corresponding columns would need to be added to the alterations by habitat tables giving the extent of each alteration in each hydrologic unit or hexagon and consistent with their current format. In addition, the severity for new alterations would need to be added to the alteration severity file.

8.3.3.1 Water Based Severity Extent Calculation.r

Input files:

1. Table listing the overlapping area-based alterations and habitat combinations per hexagon with the following fields (**hab_alt_by_hex20170612.csv**):
    a. **ALT_HABITA** – alteration habitat type, must be one of the following: "*creeks and rivers*", "*deep soft bottom*", "*shallow soft bottom*", "*SAV and shell bottom*", "*SAV*" , "*shell bottom*", "*soft bottom (ND)*", "*upland*", "*wetland*".
    b. **Unique_ID** – unique hexagon assessment unit identifier.
    c. **alt_area** – area of habitat intersection by the alteration factor in each hexagon.
    d. Fields for any polygon based alterations considered. Currently, they include the following: "*canal_bb*", "*brdge_cons*", "*impounded*", "*docks_br*", "*dredged*", "*drained*", "*marinas*", "*major_npdes*", "*trawl*"
        i. Each row gives the presence/absence (1/0) of one specific factor for each hexagon.
        ii. Each hexagon has multiple rows, one for each habitat type x factor combination.
2. Table listing the overlapping line-based alterations and linear habitat combinations per hexagon with the following fields **(alt_lines_by_hex20170612.csv)**:
    a. **ALT_HABITA** – alteration habitat type, must be one of the following: "*Stream" and "Wetland Edge"*.
    b. **Unique_ID** – unique hexagon assessment unit identifier.
    c. **alt_length** – area of habitat intersection by the alteration factor in each hexagon.
    d. Fields for any linear-based alterations considered. Currently, they include the following: "*canal_bb*", "*brdge_cons*", "*impounded*", "*docks_br*", "*dredged*", "*drained*", "*marinas*", "*major_npdes*", "*trawl*".
        i. Each row gives the presence/absence (1/0) of one specific factor for each hexagon.
        ii. Each hexagon has multiple rows, one for each habitat type x factor combination.
3. Table giving amount of each polygon habitat in each hexagon with the following fields (**hab_by_hex20170612.csv**):
    a. **ALT_HABITA** – alteration habitat type.
    b. **Unique_ID** – unique hexagon identifier.
    c. **hab_area** – total area of particular habitat type within a hexagon.
4. Table giving amount of each linear habitat in each hexagon with the following fields (**lines_by_hex20170612.csv**):
    a. **ALT_HABITA** – alteration habitat type.
    b. **Unique_ID** – unique hexagon identifier.
    c. **length_new** – total area of particular habitat type within a hexagon.
5. Alteration severity table (**alteration_factor_weighting_water20170515.csv**):
    a. **ALT_HABITA** – habitat types (rows).
    b. Alteration list – must match names exactly as they appear in the R alteration file (columns).
6. Seawalls by hexagon (**seawalls_by_hex20170612.csv**):
    a. **ALT_HABITA** –linear habitat types for alteration (wetland and non-wetland shoreline).
    b. **Unique_ID** – hexagon assessment unit unique identifier.

   c. **wall_len** – length of seawall in hexagon.
7. Length of streams with an amount ditched attribute (**lines_by_ditched_by_hex20170612.csv**). Necessary attributes:
   a. **Unique_ID** – hexagon assessment unit unique identifier.
   b. **ALT_HABITA** – linear habitat type for alteration (streams only).
   c. **ditch_le** – total length of ditched feature within each hexagon, measured in meters.
   d. **prop_ditched** – proportion of total stream length that is ditched.
   e. **length_new** – total amount of linear habitat type within each hexagon, measured in meters.
8. Length of streams with an attribute signifying the amount affected by culverts (**streams_by_culvert_by_hex20170612.csv**). Necessary attributes:
   a. **Unique_ID** – hexagon assessment unit unique identifier.
   b. **ALT_HABITA** – habitat type for alteration (streams only).
   c. **culv_len** – length of culvert-affected features, measured in meters.
9. Length of shoreline affected by riprap (**riprap_by_hex20170612.csv**). Necessary attributes:
   a. **Unique_ID** – hexagon assessment unit unique identifier.
   b. **ALT_HABITA** – habitat type for alteration (non-wetland shoreline only).
   c. **riprap_le** – length of riprap-affected shoreline, measured in meters.

Output files:

1. Severity multiplied by extent for all water based factors for each hexagon, in dbf and csv form:
   a. **WBSE_20170612.csv**
   b. **WBSE_20170612.dbf**

8.3.3.2 Land Based Severity Extent Calculations.r

Input files:

1. Table of factors for each hydrologic unit (**hu_alt_factors_table20170612.dbf**):
   a. **HU_12** – US Geological survey hydrologic unit code.
   b. **hu_area** – area of hydrologic unit in meters squared.
   c. *Scaled* values for the affected amount for each hydrologic unit:
      i. **min_npdes** – number of sites per hydrologic unit (includes aquaculture facilities) divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
      ii. **Cat_Swine_anops** – Number of cattle and swine operations per hydrologic unit divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
      iii. **Poultry_anops** – Number of poultry operations per hydrologic unit divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
      iv. **dev_use** – proportion of area of each hydrologic unit in the developed land use class.
      v. **ag_use** – proportion of area of each hydrologic unit in the agricultural land use class.

2. Table giving amount of each polygon habitat in each hexagon (**hab_by_hex20170612.csv**). The necessary attributes include:
    a. **ALT_HABITA** – polygon habitat type for alteration.
    b. **Unique_ID** – hexagon assessment unit unique identifier.
    c. **hab_area** – area of habitat in meters squared.
3. Table identifying which hydrologic unit a hexagon is in (if a hexagon has more than one hydrologic unit it will have more than one line) (**hu_by_hex20170612.csv**):
    a. **Unique_ID** – hexagon assessment unit unique identifier.
    b. **HU_12** – US Geological Survey hydrologic unit code.
    c. **hu_area** – area of each hydrologic unit.
    d. **hex_area** – area of each hexagon assessment unit unique identifier.
    e. **FREQUENCY**- number of HU's a hexagon intersects.
    f. **MAX_HEX_AR** – maximum area of hexagon in one hydrologic unit.
4. Alteration severity table (**alteration_factor_weighting_land20170515.csv**)
    a. **ALT_HABITA** – habitat types (rows).
    b. Alteration list – must match names exactly as they appear in the R alteration file (columns).
5. Intersection of closed shellfish areas with habitats in the study area (**shellfish_by_hex20170612.csv**). Necessary attributes.
    a. **ALT_HABITA** – alteration habitat type.
    b. **Unique_ID** – hexagon assessment unit unique identifier.
    c. **shell_area** – area of overlap between closed shellfish areas and alteration habitat types.

Output file:

1. **lbse_20170612.csv**
2. **lbse_20170612.dbf**

8.3.3.3 Alteration Scores.r

Combines the outputs of the previous scripts into a final alteration score file.

Inputs:

1. Severity by extent for water-based alterations (**wbse_20170612.csv**)
2. Severity by extent for land-based alterations (**lbse_20170612.csv**).
   Note: this is already aggregated so that there's one row per hexagon whereas the other severity by extent file is not.
3. Table giving amount of each polygon habitat in each hexagon (**hab_by_hex_table_no_marine.csv**)
    a. **ALT_HABITA** – alteration habitat type
    b. **Unique_ID** – hexagon assessment unit unique identifier
    c. **hab_area** – area of habitat features, measured in meters squared
4. Length of lines in each hexagon (**lines_by_hex_table.csv**)
    a. **ALT_HABITA** – linear habitat type for alteration
    b. **Unique_ID** – hexagon assessment unit unique identifier

c. **length_new** – length of feature, in meters

Outputs:

1. **AltScore_by_Hex20170613.csv** - combined alteration scores for all hexagons. Attributes:
   a. **ID** – hexagon assessment unit unique identifier.
   b. **R4_alt_score** – alteration score
2. **hab_scores20170612.csv –** alteration scores broken down by habitat type per hexagon. One line per hexagon gives the severity * extent * portion for each habitat type in each hexagon.
3. **ind_scores_20170612.csv** - alteration scores broken down by alteration factor by hexagon. One line per hexagon gives the severity * extent * portion for each alteration factor for each hexagon.

9 APPENDIX B: PREPARING THE MARXAN FILES

The Marxan documentation and good practices handbook are both comprehensive and can assist in designing and carrying out an analysis. As the documentation is quite thorough, the intent of this appendix is to give specific details about this analysis and not a complete set of instructions for using Marxan. For this analysis, the program was used in its stand-alone form and the input files prepared using ArcGIS, Excel and R. User interfaces such as Zonae Cogito (Watts et al.) are available for users that are less familiar with ArcGIS.

Marxan version 2.4.3 was used for this analysis. There is currently no official user's manual for this version and some differences exist between it and the previous versions. The accompanying README text file explains the major changes. The biggest difference is in the format of the species vs. planning unit file and is described below. Formatting of the input files seems consistent with the formats described in the Marxan with zones handbook (Watts et al. 2008), which was used to cross-reference formatting questions.

Marxan requires four data files and an input file in order to run. They are all text files (either tab or comma delimited) that have been renamed with the extension .dat. The file names can be changed but they must have the correct extension for Marxan to work properly. There are a specific set of column names that are required for each file. They must be present and match the descriptions given in the handbook in order for Marxan to read the input files.

9.1 Species File (spec.dat)

This contains information on all conservation features in the analysis. It assigns each conservation feature (NRT) a unique numerical id, which is uses to relate to the other Marxan input files, and gives the target amounts (or proportion) for each conservation feature in the final solution, and assigns each conservation feature a species protection factor. In addition, it can contain a name for each conservation feature. For Region 4, this was made in Excel and exported to a csv.

Example species file:

id	target	name	spf
1	0	Emergent_wetland	100
2	2796820	Est_soft_bottom_deep	100
3	14916712	Est_soft_bottom_shallow	100
4	2838143	Est_soft_bottom_mid	100
5	0	Est_soft_bottom_ND	100
6	71188072	Forested_wet	100

9.2 Planning Units File (pu.dat)

This is a list giving the planning units in the study area, their cost, and their status. Alteration score was used as the cost. We assigned planning units defined as inlets to have a status of ‘2’, which means they must be included in the final solution. Other options for status are to include a planning unit in the initial solution, or to exclude a planning unit from the final solution. This was created in ArcGIS by joining the alteration score to the planning unit shapefile and exported to a csv.

Example planning unit file:

id	cost	status
1	2.000000	0
2	5.490000	0
3	2.000000	0
4	2.000000	0
5	2.000000	0
6	1.000000	0
7	1.900000	0
9	1.000000	0
10	1.000000	0

9.3 Boundary Tile (bound.dat)

The boundary file gives the length of the boundary between adjacent files. It is in the format of id1, id2, and amount. For the Region 4 analysis it was created in ArcGIS, using the tool ‘Make Boundary file’ in the SHA tools toolbox. This tool requires a layer file of the planning units as an input. The input layer file must have a field called ‘MarxID’ and the workspace should be set to the default geodatabase. The tool outputs a DBF file, which can be converted to a csv using Excel.

Example boundary file:

id1	id2	boundary
1	14650	225.000073
1	14651	225.000000
1	14861	225.000000
2	9281	225.000000
2	9339	225.000000
2	9340	224.99998
3	7745	225.000000
3	8011	225.000000

9.4 Planning Units vs. Species File (puvspr.dat)

This file gives the amount of each conservation feature in each planning unit. Marxan version 2.4.3 differs from previous Marxan in that it will only read the long format, where each combination of planning unit and conservation feature is in a separate row. Previous versions of Marxan were configured to accept this table in the wide format, where each planning unit was a row and the conservation features were the columns. The Marxan software comes with a utility (convert_mtx.exe) to convert records from the long to wide format and vice versa. The file needs to be ordered by the planning unit, and then species ID. This file was made in ArcGIS by intersecting the planning unit with the polygon habitat shapefiles (R4_NRTs). These three tables were exported as DBFs, concatenated and then sorted by planning unit and then species in Excel.

Example planning unit vs species file.

Species	pu	amount
10	1	131527.61
3	2	13031.22
7	2	560.42
10	2	5995.63
11	2	16166.99
12	2	8248.68
13	2	7.25
25	2	13798

9.5 The Input File (input.dat)

Sets the Marxan specifications for the analysis. Marxan comes with an executable called InEdit.exe. that guides the user through all of the Marxan options and generates the input file.

9.6 Marxan Resources:

Watts, M. E., R.R. Stewart, D. Segan, L. Kircher: Using the Zonae Cogito Decision Support System, a Manual.

Ball, I. R., H. P. Possingham, and M. Watts. 2009. Marxan and relatives: software for spatial conservation prioritisation. Pages 185-195 *in* A. Moilanen, K. A. Wilson, and H. P. Possingham, editors. Spatial conservation prioritisation: quantitative methods and computational tools. Oxford University Press, Oxford, United Kingdom.

Ball, I.R., and H.P. Possingham, 2000. MARXAN (V1.8.2): Marine Reserve Design Using Spatially Explicit Annealing, a Manual.

Game, E.T. and H.S. Grantham, 2008. Marxan User Manual: For Marxan version 1.8.10. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Watts, M.E., C.K. Klein, R. R. Stewart, I. R. Ball, and H. P. Possingham. 2008. Marxan with Zones (V1.0.1): Conservation Zoning using Spatially Explicit Annealing, a Manual.

10 APPENDIX C: DATA/INFORMATION DIRECTORY

Region 4 SHA Natural Resource Target and Alteration Factor GIS models and files:

See Appendix A: Natural Resource Targets and Calculating Total Alteration Section 8.1 Processing Details for further details.

S:\HABITAT\CHPP\SHA\Region 4\GIS\

Models\

1. SHA R4.tbx
2. Final Alteration Tools.tbx

Inputs\AlterationFactors\Finals

1. R4_Bridges.shp
2. R4_Bulkheads_RipRap_Final.shp
3. R4_CAFOsbyHUC.shp
4. R4_CAFOsbyHUC_Poultry.shp
5. R4_Canals_Boat_Basins.shp
6. R4_CCAP_2010_AgHUC_Final.shp
7. R4_CCAP_2010_DevHUC_Final.shp
8. R4_Culverts.shp
9. R4_Dams.shp
10. R4_Ditched_Final.shp
11. R4_DocksandPiers.shp
12. R4_DredgedChannels.shp
13. R4_Major_NPDES_HUC.shp
14. R4_Marinas_SGA_Closures.shp
15. R4_Mechanical_clam_harvesting_areas.shp
16. R4_Minor_NPDES_HUC.shp
17. R4_ProhibitedShellfishHarvest.shp
18. R4_Trawling_allowed

Inputs\Boundaries

1. Region4.shp
2. R4_USGS_HUCs
3. R4_trip_ticket_water_bodies.shp
4. R4_Hex20170615.shp
5. R4_A24k_jurisditional_waters.shp
6. R4_500m_FocusArea.shp
7. R4_Hexagons225SL_FocusArea.shp

Inputs\NRTs\Finals

1. ALT_HABITA_Poly20170508.shp
2. NRT_by_Hex20170619.shp
3. R4_ContiguousWetlands_W_FA.shp

4. R4_HardBottom_Final.shp
5. R4_NRTs_20170619.shp
6. R4_SAV_Final.shp
7. R4_SAV_ShellBottom_Final.shp
8. R4_ShellBottom_Final.shp
9. R4_Streams_Final.shp
10. R4_WetlandEdge_Final.shp
11. R4_WetlandEdge_w_FA.shp
12. StreamsUplandRiparian.shp

Region 4 SHA R script input/output files:

See Appendix A: Natural Resource Targets and Calculating Total Alteration Section 8.3 Extent Calculations for further details.

S:\HABITAT\CHPP\SHA\Region 4\GIS\Data
1. alt_lines_by_hex20170612.csv
2. alt_scores_20170612.csv
3. alteration_factor_weighting_land20170515.csv
4. alteration_factor_weighting_water20170515.csv
5. hab_alt_by_hex20170612.csv
6. hab_by_hex20170612.csv
7. hab_scores20170612.csv
8. hu_alt_factors_table20170508.csv
9. hu_by_hex20170612.csv
10. ind_scores_20170612.csv
11. LBSE_20170612.csv
12. lines_by_ditch_by_hex20170612.csv
13. lines_by_hex20170612.csv
14. NRT_by_hex20170613.csv
15. riprap_by_hex20170612.csv
16. seawalls_by_hex20170612.csv
17. shellfish_by_hex20170612.csv
18. shoreline_by_hex20170612.csv
19. streams_by_culvert_by_hex20170612.csv
20. WBSE_20170612.csv

Region 4 SHA R script files:

S:\HABITAT\CHPP\SHA\Region 4\GIS\R Scripts
1. alteration scores final_20170405.r
2. water based severity extent calculations_final.r
3. land based severity extent calculations_20170421.r
4. output_processing.r

Region 4 SHA Marxan files:

See Section 9 Appendix B: Preparing the Marxan files for further details.

S:\HABITAT\CHPP\SHA\Region 4\GIS\Marxan2.4.3

1. Marxan.exe
2. Inedit.exe
3. Input.dat

\input

1. Bound.dat
2. Pu.dat
3. Puvspr.dat
4. Spec.dat

11 APPENDIX D: PUBLIC COMMENT

To be completed after public comment

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

May 17, 2018

MEMORANDUM

TO:	Marine Fisheries Commission
FROM:	Catherine Blum, Fishery Management Plan and Rulemaking Coordinator Fisheries Management Section
SUBJECT:	Rulemaking Update

This memo describes the materials about the rulemaking update for the May 2018 commission meeting. In accordance with requirements of G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules, the commission is scheduled to vote on approval to begin the rule readoption process for a portion of rules in 15A NCAC 03. This includes approval of the proposed text of the rules and the fiscal analysis of the rules, as approved by the Office of State Budget and Management. Background information is provided here, including recent actions that have occurred, followed by a summary of items scheduled for the commission to take action on at this meeting.

Additional handouts are provided in your briefing book, including figures showing the steps in the commission's 2018-2019 annual rulemaking cycle and the associated rules prepared for the readoption process. The approved fiscal analyses are also provided and each of these documents contains an appendix with the text of the corresponding proposed rules.

Background on the Periodic Review and Expiration of Existing Rules

Session Law 2013-413, the Regulatory Reform Act of 2013, implemented requirements known as the "Periodic Review and Expiration of Existing Rules." These requirements are codified in a new section of Article 2A of Chapter 150B of the General Statutes in G.S. 150B-21.3A. Under the requirements, each agency is responsible for conducting a review of all its rules at least once every 10 years in accordance with a prescribed process.

The review has two parts. The first is a report phase, followed by the readoption of rules. An evaluation of the rules under the authority of the Marine Fisheries Commission is being undertaken in two lots (see Figure 1.) A report on the rules in Title 15A, Environmental Quality, Chapter 03, Marine Fisheries was due to the Rules Review Commission December 2017. A report on the rules in Chapter 18, Environmental Health, for portions of Subchapter A that govern shellfish sanitation and recreational water quality is due January 2019. The Marine Fisheries Commission has 211 rules in Chapter 03 and 164 rules in Chapter 18A. The Marine Fisheries Commission is the body with the authority for the approval steps prescribed in the process for these rules.

Figure 1. Marine Fisheries Commission schedule to comply with G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules.

<table>
<tr><th>Rules</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th></tr>
<tr><td>Chapter 03
(211 rules)</td><td>Report</td><td colspan="4">Rule Readoption</td><td></td></tr>
<tr><td>Chapter 18A
(164 rules)</td><td></td><td>Report</td><td colspan="4">Rule Readoption</td></tr>
</table>

The process began for the Marine Fisheries Commission at its February 2017 business meeting with approval of the draft report on the rules in Title 15A, Environmental Quality, Chapter 03, Marine Fisheries. This report contained 211 rules and was reviewed by the Rules Review Commission December 2017.

Nine of these 211 rules are jointly adopted by the Marine Fisheries Commission and the Wildlife Resources Commission. The rules are subtitled "Jurisdiction of Agencies: Classification of Waters" and are found in 15A NCAC 03Q .0100. Similarly, the Wildlife Resources Commission has 11 rules that are jointly adopted and have the same subtitle; they are found in 15A NCAC 10C .0100. For the required steps in the periodic review process, both agencies must approve both sets of rules, since the rules were all jointly adopted. The approvals for the draft report on these rules occurred at the Marine Fisheries Commission's February and May 2017 business meetings and the Wildlife Resources Commission's April 2017 meeting.

For the reports, the first step is for each agency to make a determination as to whether each rule is necessary with substantive public interest, necessary without substantive public interest, or unnecessary. After the draft reports are approved, they are posted on the Division of Marine Fisheries website for public comment for a minimum of 60 days. It is important to note, for the purposes of these requirements, "public comment" means written comments from the public objecting to the rule. The agency must review the public comments and prepare a brief response addressing the merits of each comment. This information becomes the final report.

The final report for rules in 15A NCAC 03Q .0100 and the final report for all other rules in 15A NCAC 03 were reviewed and approved by the Rules Review Commission at its December 2017 meeting. The reports were forwarded to the Joint Legislative Administrative Procedure Oversight Committee for final determination. The committee met Jan. 9, 2018 and the review process was completed for these rules.

The second part of the periodic review process is the readoption of rules; this is scheduled to begin for the Marine Fisheries Commission May 2018. The final report determines the process for readoption. Rules determined to be necessary and without substantive public interest and for which no public comment was received remain in effect without further action. Rules determined

Nothing Compares
State of North Carolina | Division of Marine Fisheries
3441 Arendell Street | P.O. Box 769 | Morehead City, North Carolina 28557
252-726-7021

to be unnecessary and for which no public comment was received expire on the first day of the month following the date the report becomes effective. Rules determined to be necessary with substantive public interest must be readopted as though the rules were new rules. The Rules Review Commission works with each agency to consider the agency's rulemaking priorities in establishing a deadline for the readoption of rules.

The final determinations for the rules in 15A NCAC 03Q .0100 and all other rules in 15A NCAC 03 were unchanged from how they were submitted. As a result, three rules were determined to be unnecessary and expired, 36 rules were determined to be necessary without substantive public interest and remained in effect without further action, and 172 rules were determined to be necessary with substantive public interest and must be readopted as though they were new rules. The next step in the process is to set a readoption schedule.

Recent Actions for the Periodic Review and Expiration of Existing Rules

Readoption Schedule for 15A NCAC 03 Rules

The process of rule readoption is scheduled to begin at the Marine Fisheries Commission's May 2018 business meeting. Given the large number of rules subject to readoption, this will be the first of several years proposed to readopt rules. In preparation for the May meeting, staff prepared a readoption schedule for the 15A NCAC 03 rules. At its February 2018 meeting, the commission approved the schedule for readoption of these rules to be completed by June 30, 2022. To achieve this, staff will prepare approximately 40 to 45 rules in 15A NCAC 03 for readoption in each of four years. For the 2018-2019 rule package, the proposed rules have been recently amended and/or need only technical changes. The rules have no anticipated costs associated with them and will benefit stakeholders with increased clarity and consistency across rules. The rules are intended to become effective April 1, 2019.

The proposed readoption schedule, as approved by the Marine Fisheries Commission, was submitted to the Rules Review Commission for approval. Due to the nature of the jointly-adopted rules of the Marine Fisheries Commission and the Wildlife Resources Commission, the Wildlife Resources Commission is also part of the process of approving the readoption schedule, as shown by its April 2018 meeting agenda. The readoption schedule is slated for approval by the Rules Review Commission at its May 2018 meeting. The schedule must be approved by the Rules Review Commission prior to publication of proposed rules in the *N.C. Register*. The Marine Fisheries Commission can take action to begin the rulemaking process at its May 2018 business meeting.

Draft Report on 15A NCAC 18A Rules

At its February 2018 meeting, the Marine Fisheries Commission gave approval to begin the report process for the 164 rules in 15A NCAC 18A .0100, .0300-.0900, and .3400, regarding shellfish sanitation and recreational water quality requirements. All rules were classified as necessary with substantive public interest and are subject to readoption. The process will follow the same timing that occurred in 2017 for the previous rule reports. A public comment period is being held for the rules in 15A NCAC 18A .0100, .0300-.0900, and .3400 from Feb. 26-May

7, 2018; no public comments have been received to date. If public comments are received, staff will review the public comments and prepare a brief response addressing the merits of each comment. This information becomes the final report. The final report will be presented to the Marine Fisheries Commission at its August 2018 meeting and is due to the Rules Review Commission by January 2019.

2018/2019 Notice of Text for Rulemaking to Readopt Rules per G.S. 150B-21.3A

In accordance with requirements of G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules, the commission is scheduled to vote on approval to begin the rule readoption process for a portion of rules in 15A NCAC 03. This includes approval of the proposed text of the rules and the fiscal analysis of the rules, as approved by the Office of State Budget and Management. The rules have an intended effective date of April 1, 2019.

Associated handouts are provided in your briefing book, including two figures. The first figure shows the steps in the commission's 2018-2019 annual rulemaking cycle and the second provides a list of the associated rules prepared for the readoption process in this first of four years. The two approved fiscal analyses are also provided and each of these documents contains an appendix with the text of the corresponding proposed rules. Although G.S. 150B-21.3A(d) exempts an agency from the requirement to prepare a fiscal note for a rule that is readopted without substantive change, the Marine Fisheries Commission's rules remain subject to the requirements of Section 2 of Executive Order 70 under Governor Perdue. These requirements include that an agency "shall quantify the costs and benefits to all parties of a rule to the greatest extent possible. The level of analysis shall be proportional to the significance of the rule."

The first fiscal analysis is entitled "Conforming Changes to For-Hire Licenses" and addresses proposed changes to 15A NCAC 03O .0112. These changes amend the rule to conform to changes that previously occurred in an authorizing statute. Session Law 2013-360 made statutory changes to the way for-hire licenses are structured, creating three new licenses. This law also required certain for-hire operations to obtain a Commercial Fishing Vessel Registration with a for-hire endorsement for their vessel. Updating the rule will provide consistency with rules and statutes pertaining to for-hire licenses as well as provide clarity for affected stakeholders.

The second analysis is entitled "Readoption of a Portion of Rules in 15A NCAC 03I, 03J, 03K, 03L, 03M, 03O, and 03R" and addresses amendments that are of an administrative nature to update rules. The rules have no anticipated costs associated with them and will benefit stakeholders with increased clarity and consistency across rules. Amendments include deleting two obsolete permits (Albemarle Sound Management Area for River Herring Dealer Permit; Permit to Waive the Requirement to use Turtle Excluder Devices in the Atlantic Ocean), alphabetizing permits, and making other conforming and minor technical changes.

Staff recommends the commission approve the following proposed rules and associated fiscal analyses for Notice of Text for Rulemaking to readopt rules per G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules:

- Conforming Changes to For-Hire Licenses, 15A NCAC 03O .0112; and
- Readoption of a Portion of Rules in 15A NCAC 03I, 03J, 03K, 03L, 03M, 03O, and 03R.

N.C. Marine Fisheries Commission
2018-2019 Annual Rulemaking Cycle

May 2018

Time of Year	Action
January 2018	Last opportunity for a new issue to be presented to DMF Rules Advisory Team
February 2018	Second review by DMF Rules Advisory Team
February-April 2018	Fiscal analysis of rules prepared by DMF staff and approved by Office of State Budget and Management
May 2018	MFC considers approval of Notice of Text for Rulemaking
August 2018	Publication of proposed rules in the North Carolina Register
September 2018	Public hearing(s) held
November 2018	MFC considers approval of permanent rules
January 2019	Rules reviewed by Office of Administrative Hearings Rules Review Commission
(January)	(Last opportunity for a new issue to be presented to DMF Rules Advisory Team)
(February)	(Second review by DMF Rules Advisory Team)
February 1, 2019	Earliest possible effective date of rules
February/March 2019	Rulebook prepared
April 1, 2019	Actual effective date of new rules
April 1, 2019	Rulebook available online
April 15, 2019	Commercial license sales begin

Proposed Readoption Schedule for 15A NCAC 03
Year 1 of 4: 2018-2019 (41 rules)
May 1, 2018

Rule Citation	Rule Name
15A NCAC 03I .0120	POSSESSION OR TRANSPORTATION LIMITS
15A NCAC 03J .0101	FIXED OR STATIONARY NETS
15A NCAC 03J .0102	NETS OR NET STAKES
15A NCAC 03J .0108	NETS PULLED BY MORE THAN ONE BOAT
15A NCAC 03J .0203	CHOWAN RIVER AND ITS TRIBUTARIES
15A NCAC 03J .0204	CURRITUCK SOUND AND ITS TRIBUTARIES
15A NCAC 03J .0206	SOUTHPORT BOAT HARBOR
15A NCAC 03J .0207	DUKE ENERGY PROGRESS BRUNSWICK NUCLEAR PLANT INTAKE CANAL
15A NCAC 03J .0209	ALBEMARLE SOUND/CHOWAN RIVER RIVER HERRING MANAGEMENT AREAS
15A NCAC 03J .0303	DREDGES AND MECHANICAL METHODS PROHIBITED
15A NCAC 03J .0304	ELECTRICAL FISHING DEVICE
15A NCAC 03K .0402	SEASON, SIZE AND HARVEST LIMITS
15A NCAC 03K .0403	DISPOSITION OF MEATS
15A NCAC 03K .0404	DREDGES/MECHANICAL METHODS PROHIBITED AND OPEN SEASON
15A NCAC 03K .0405	OYSTERS, MUSSELS, HARD CLAMS PROHIBITED
15A NCAC 03K .0501	BAY SCALLOP HARVEST MANAGEMENT
15A NCAC 03K .0502	TAKING BAY SCALLOPS AT NIGHT AND ON WEEKENDS
15A NCAC 03K .0503	PROHIBITED BAY SCALLOP DREDGE
15A NCAC 03K .0504	CALICO SCALLOP SEASON
15A NCAC 03K .0507	MARKETING SCALLOPS TAKEN FROM SHELLFISH LEASES OR FRANCHISES
15A NCAC 03K .0508	SCALLOP SEASON AND HARVEST LIMIT EXEMPTIONS
15A NCAC 03L .0208	STONE CRABS (MENIPPE MERCENARIA)
15A NCAC 03M .0101	MUTILATED FINFISH
15A NCAC 03M .0102	UNMARKETABLE FINFISH
15A NCAC 03M .0103	MINIMUM SIZE LIMITS
15A NCAC 03M .0501	RED DRUM
15A NCAC 03M .0502	MULLET
15A NCAC 03M .0506	SNAPPER-GROUPER COMPLEX
15A NCAC 03M .0507	BILLFISH
15A NCAC 03M .0510	AMERICAN EEL
15A NCAC 03M .0513	RIVER HERRING
15A NCAC 03M .0515	DOLPHIN
15A NCAC 03M .0517	WAHOO
15A NCAC 03M .0518	KINGFISH (SEA MULLET)
15A NCAC 03M .0520	TUNA
15A NCAC 03M .0521	SHEEPSHEAD
15A NCAC 03O .0106	DISPLAY OF LICENSES AND REGISTRATIONS
15A NCAC 03O .0112	FOR HIRE COASTAL RECREATIONAL FISHING *
15A NCAC 03O .0501	PROCEDURES AND REQUIREMENTS TO OBTAIN PERMITS
15A NCAC 03O .0503	PERMIT CONDITIONS; SPECIFIC
15A NCAC 03R .0112	ATTENDED GILL NET AREAS

* See "Regulatory Impact Analysis of Proposed Rule 15A NCAC 03O .0112 Conforming Changes to For-Hire Licenses". All other rules are addressed by "Regulatory Impact Analysis for Readoption of a Portion of Rules in 15A NCAC 03I, 03J, 03K, 03L, 03M, 03O, and 03R".

Regulatory Impact Analysis of Proposed Rule 15A NCAC 03O. 0112

Conforming Changes to For-Hire Licenses

Rule Amendments: 15A NCAC 03O .0112

Name of Commission: N.C. Marine Fisheries Commission

Agency Contact: Adam Stemle, Fisheries Economics Program Manager
N.C. Division of Marine Fisheries
3441 Arendell Street
Morehead City, NC 28557
(252) 808-8107
adam.stemle@ncdenr.gov

Impact Summary:

State government:	No
Local government:	No
Federal government:	No
Substantial impact:	No

Authority:

North Carolina Marine Fisheries Commission Rules May 1, 2015
(see Appendix I)
15A NCAC 03O. 0112 For-Hire Coastal Recreational Fishing

North Carolina Session Laws (see Appendix II)
North Carolina Session Law 2006-255, Section 7
North Carolina Session Law 2006-259, Section 20.5
North Carolina Session Law 2013-360, Section 14.8(e); Section 14.8(n); Section 14.8(o) [See Appendix 2]

North Carolina General Statutes (see Appendix III)
G.S. 113-168.6 Commercial fishing vessel registration
G.S. 113-174.3 For-Hire Licenses

Necessity: Session Law 2013-360 made statutory changes to the way for-hire licenses are structured, creating three new licenses. This law also required certain for-hire operations to obtain a Commercial Fishing Vessel Registration (CFVR) with a for-hire endorsement for their vessel. Current Marine Fisheries Commission (MFC) rules need to be amended to conform to the existing statute.

The anticipated effective date of the proposed rule changes is April 1, 2019

I. Summary

To address deficiencies and inequities in the for-hire licensing structure, the North Carolina Division of Marine Fisheries (DMF) proposed changes to the license structure to include a blanket captain's license, a blanket vessel license, and a non-blanket vessel license. These three licenses were incorporated into G.S. 113-174.3 in 2013. The original For-Hire Blanket CRFL was eliminated from the statute and the For-Hire Fishing Permit was discontinued June 30, 2014. The Marine Fisheries Commission (MFC) removed the For-Hire Fishing Permit requirement from Rule 15A NCAC 03O .0503 effective May 1, 2015, but Rule 15A NCAC 03O .0112 still references this permit and has yet to be updated to reflect the for-hire licenses currently found in G.S. 113-174.3. Paragraph (d) of Rule 15A NCAC 03O .0112 is still relevant and the content was added to 15A NCAC 03O .0106 (Display of Licenses and Registrations), also effective May 1, 2015; therefore, Paragraph (d) needs to be removed from 15A NCAC 03O .0112, as it is redundant. Updating the accompanying rule will provide consistency with rules and statutes pertaining to for-hire licenses as well as provide clarity for affected stakeholders.

II. Introduction and Purpose of Rule Changes

In July 1994, the North Carolina General Assembly established the Moratorium Steering Committee (MSC) to study North Carolina's entire coastal fisheries management process and to recommend changes to improve the licensing system. Within the MSC, a License Sub-committee was established and charged with, among other things, examining in detail the licensing of the for-hire fishing sector.

The findings and recommendations of the MSC served as the framework for development and passage of the Fisheries Reform Act of 1997. Within the MSC final report were provisions for for-hire vessel licenses and recreational fishing licenses. However, these provisions were not included in the final legislation. Ten years later, these recommendations were implemented by additional legislation.

To establish a system to provide management tools for monitoring the for-hire industry in the interim, the Marine Fisheries Commission utilized rule-making authority to establish a provisional no-cost For-Hire Fishery Permit in 2003. Several years after the permit requirement was established, new laws were passed in North Carolina creating a Coastal Recreational Fishing License (CRFL). In part, this was done to provide management tools for monitoring recreational anglers. During the 2003 Session, the General Assembly of North Carolina passed a CRFL requirement (G.S. 113-174 *et. seq.*) which became effective January 1, 2007. One of the new laws, G.S. 113-174.3 pertained directly to the optional Blanket For-Hire CRFL, which established fees and removed responsibility for licensure of angling customers from the individual and placed it on the owner or operator of the vessel. Having a database of for-hire participants allowed the DMF to survey the industry for effort information as part of the For-Hire Survey that DMF conducts as a contractor to the National Marine Fisheries Service. It also satisfied requirements of the National Angler Registry as put forth in the federal Magnusson-Stevens Reauthorization Act of 2006[1] (NOAA, 2007).

This component of the CRFL for an optional for-hire blanket license covered anglers' licensing requirements if they were aboard a properly licensed for-hire boat. The for-hire blanket license was available to USCG-licensed captains who carried six or fewer passengers (guides and charter boats) as well as a separate license for USCG-certified vessels carrying more than six passengers (headboats) and operated by a USCG-licensed captain. The price was $250 for six or

[1] Magunson-Stevens Fishery Conservation and Management Act. As Amended Through January 12, 2007. May 2007. National Oceanic and Atmospheric Administration. National Marine Fisheries Service. http://www.nmfs.noaa.gov/msa2005/docs/MSA_amended_msa%20_20070112_FINAL.pdf

fewer passengers and $350 for more than six passengers, with nonresidents paying the same fee as residents.

In March of 2011, the DMF held three meetings throughout coastal North Carolina with members of the for-hire industry to get industry feedback on changes to the license structure, logbooks, and other issues the industry may have. Inequities and inefficiencies in the license design were brought to DMF's attention during the for-hire stakeholders meetings. Recommendations from the series of meetings were drafted in the *Summary of the 2011 For-Hire Stakeholders Meetings Report to the Marine Fisheries Commission*[2]. The MFC agreed with the recommendations which were then incorporated into DMF's request for statutory amendments to the N.C. General Assembly. These recommendations were adopted by the 2013 session of the General Assembly in Session Law 2013-360.

Session Law 2013-360 made statutory changes in G.S. 113-168.6 and G.S. 113-174.3 that alter the way for-hire licenses are structured, require certain for-hire operations to obtain Commercial Fishing Vessel Registrations (CFVR) with for-hire endorsements for their vessels, and obligate for-hire operators to affirm liability coverage and knowledge of USCG safety requirements.

Current for-hire licenses are as follows:

1. The Blanket For-Hire Captain's CRFL allows the holder to use any properly licensed vessel in his/her operation while covering the licensing requirements of the anglers. All vessels operated by the holder of a Blanket For-Hire Captain's CRFL must have a CFVR with a for-hire endorsement. This license satisfies recreational fishing license requirements, but without the CFVR with a for-hire endorsement, does not satisfy for-hire licensing requirements. The Blanket For-Hire Captain's CRFL was developed primarily for inshore fishing guides who operate multiple vessels. The fee is the same as the Blanket For-Hire Vessel CRFL but should result in a cost savings to resident fishing guides who operate multiple vessels since the accompanying CFVR with for-hire endorsement is considerably less expensive than the Blanket For-Hire Vessel CRFL and is based on vessel length. The holder of this license must also be a United States Coast Guard (USCG) licensed captain.

2. The Blanket For-Hire Vessel CRFL is a license issued to the vessel and must be operated by a USCG licensed captain. This license was developed primarily for the headboat industry where oftentimes multiple captains operate one headboat vessel at different times, resulting in potential cost savings for a vessel owner. A vessel owner can simply license the vessel instead of obtaining a license for each captain who might operate that vessel.

3. The Non-Blanket For-Hire Vessel License (note: not a CRFL) is also a license issued to the vessel. This license satisfies for-hire licensing requirements, but does not intersect with recreational fishing license requirements. It was developed primarily for the dive boat industry that infrequently has divers who wish to spear fish. Spear fishermen on a dive boat licensed with a Non-Blanket For-Hire Vessel License must obtain an individual CRFL to legally take fish. It is possible that many inshore fishing guides may seek to purchase this

[2] Available at http://portal.ncdenr.org/c/document_library/get_file?uuid=a1055e24-5169-4ddb-aa9d-c8cd422ecf9d&groupId=38337

license if they do not wish to cover their anglers' licensing requirements. The vessel must be operated by a USCG licensed captain.

The original For-Hire Blanket CRFL was eliminated from the statute and the For-Hire Fishing Permit was discontinued June 30, 2014. The MFC removed the For-Hire Fishing Permit requirement from Rule 15A NCAC 03O .0503 effective May 1, 2015, but Rule 15A NCAC 03O .0112 still references this permit and has yet to be updated to reflect the for-hire licenses currently found in G.S. 113-174. Paragraph (d) of Rule 15A NCAC 03O .0112 is still relevant and the content was added to 15A NCAC 03O .0106 (Display of Licenses and Registrations), also effective May 1, 2015; therefore, Paragraph (d) needs to be removed from 15A NCAC 03O .0112, as it is redundant.

Additionally, G.S. 150B-19.1, part of the Administrative Procedure Act, sets forth the principles of rulemaking. These principles include that rules shall be written in a clear and unambiguous manner and that rules shall be based on sound, reasonably available scientific, technical, and other relevant information. Amending the rule to conform to the statute will comply with the statutory requirements for rulemaking.

III. Benefits

While there are no quantifiable economic benefits to the proposed rule change, the public and law enforcement will benefit from changing rule 15A NCAC 03O .0112 to align with current management practices and to use terms as found in the current statute.

IV. Costs

There are no anticipated costs associated with the proposed rule changes, as rule changes reflect current management practices.

Appendix I Proposed Rule Changes:

15A NCAC 03O .0112 ~~FOR HIRE COASTAL RECREATIONAL FISHING~~ FOR-HIRE LICENSE REQUIREMENTS

~~(a) It is unlawful to operate a For Hire Vessel unless the vessel operator possesses either the For Hire Blanket Coastal Recreational Fishing License (CRFL) for the vessel or a Division of Marine Fisheries For Hire Fishing Permit for the vessel as provided in 15A NCAC 03O .0503(k).~~

(a) The license requirements for the operator of a vessel engaged in a for-hire operation are set forth in G.S. 113-174.3. Either the vessel owner or the for-hire vessel operator may seek to obtain the applicable for-hire vessel license. Only the vessel owner may seek to obtain the applicable registration and endorsement as set forth in G.S. 113-168.6. For the purpose of this Rule, "for-hire vessel operator" includes the holder of a Blanket For-Hire Captain's Coastal Recreational Fishing License, Blanket For-Hire Vessel Coastal Recreational Fishing License, or Non-Blanket For-Hire Vessel License, as set forth in G.S. 113-174.3.

(b) To be eligible for a for-hire license, an applicant shall meet the requirements as set forth in Rule .0101(a) of this Section.

(c) The for-hire vessel operator shall follow the requirements for display of licenses and registrations for a vessel engaged in for-hire recreational fishing as set forth in Rule .0106 of this Section.

~~(b) It is unlawful for a For Hire Vessel operator to operate under the For Hire Blanket CRFL without:~~

- ~~(1) Holding the USCG certification required in 15A NCAC 03O .0101(a)(13);~~
- ~~(2) Having the For Hire Blanket CRFL for the vessel or copy thereof in possession and ready at hand for inspection; and~~
- ~~(3) Having current picture identification in possession and ready at hand for inspection.~~

~~(c)~~(d) It is unlawful for ~~the holder of the For Hire Blanket CRFL~~ a for-hire vessel operator to fail to participate in survey programs administered by the Division of Marine Fisheries and ~~provide accurate information as requested by the Division for~~ comply with biological sampling as requested by the Division.~~and survey programs.~~

~~(d) It is unlawful to fail to display a current For Hire Blanket CRFL decal mounted on an exterior surface of the vessel so as to be visible when viewed from the port side while engaged in for-hire recreational fishing.~~

Authority G.S. 113-134; 113-168.6; 113-174.1; 113-174.3; 143B-289.52

Appendix II Excerpts of North Carolina Session Laws:

GENERAL ASSEMBLY OF NORTH CAROLINA
SESSION 2005

SESSION LAW 2006-255
SENATE BILL 1587

. . .

The General Assembly of North Carolina enacts:

. . .

SECTION 7. G.S. 113-174.3(a) reads as rewritten:
"(a) License. – A person who operates a for hire boat may purchase a For Hire Blanket CRFL issued by the ~~Division~~.Division for the for hire boat. A For Hire Blanket CRFL authorizes all individuals on the for hire boat who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. A For Hire Blanket CRFL does not authorize individuals to engage in recreational fishing in joint fishing waters or inland fishing waters. This ~~license~~A For Hire Blanket CRFL is valid for a period of one year from the date of issuance. The fee for a For Hire Blanket CRFL is:

(1) Two hundred fifty dollars ($250.00) for a vessel captained by an individual who holds a certification from the United States Coast Guard to carry six or fewer passengers.

(2) Three hundred fifty dollars ($350.00) for a vessel captained by an individual who holds a certification from the United States Coast Guard to carry greater than six passengers."

. . .

GENERAL ASSEMBLY OF NORTH CAROLINA
SESSION 2005

SESSION LAW 2006-259
SENATE BILL 1523

. . .

The General Assembly of North Carolina enacts:

. . .

SECTION 20.5. If Senate Bill 1587, 2005 Regular Session, becomes law, then G.S. 113-174.3(a), as enacted by that act, reads as rewritten:

"(a) License. – A person who operates a for hire boat may purchase a For Hire Blanket CRFL issued by the Division. A For Hire Blanket CRFL authorizes all individuals on the for hire boat who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. A For Hire Blanket CRFL does not authorize individuals to engage in recreational fishing in joint fishing waters or inland fishing waters. This license is valid for a period of one year from the date of issuance. The fee for a For Hire Blanket CRFL is:

(1) Two hundred fifty dollars ($250.00) for a vessel ~~captained by an individual who holds a certification from the United States Coast Guard to~~ that will carry six or fewer passengers.

(2) Three hundred fifty dollars ($350.00) ~~for a vessel captained by an individual who holds a certification from the United States Coast Guard to~~ that will carry greater than six passengers."

. . .

GENERAL ASSEMBLY OF NORTH CAROLINA
SESSION 2013

SESSION LAW 2013-360
SENATE BILL 402

. . .

The General Assembly of North Carolina enacts:

. . .

SECTION 14.8.(e) G.S. 113-168.6 reads as rewritten:

"**§ 113-168.6. Commercial fishing vessel registration.**

(a) As used in this subsection, a North Carolina vessel is a vessel that has its primary situs in the State. A vessel has its primary situs in the State if:

(1) A certificate of number has been issued for the vessel under Article 1 of Chapter 75A of the General Statutes;

(2) A certificate of title has been issued for the vessel under Article 4 of Chapter 75A of the General Statutes; or

(3) A certification of documentation has been issued for the vessel that lists a home port in the State under 46 U.S.C. § 12101, et seq., as amended.

(b) The owner of a vessel used in a commercial fishing operation in the coastal fishing waters of the State or a North Carolina vessel used to land or sell fish in the State shall register the vessel with the Division. It is unlawful to use a vessel that is not registered with the Division in a commercial fishing operation or a for-hire operation in the coastal fishing waters of the

State. It is unlawful to use a North Carolina vessel that is not registered with the Division to land or sell fish in the State. No registration is required for a vessel of any length that does not have a motor if the vessel is used only in connection with another vessel that is properly registered.

(b1) The vessel owner at the time of application for registration under subsection (b) of this section shall obtain either a commercial vessel endorsement if the vessel is intended to be used primarily for the harvest of fish for sale, a for-hire endorsement if the vessel is intended to be used primarily for for-hire activities, or both endorsements if the vessel is intended to be engaged in both activities. The owner of a vessel applying for a commercial fishing vessel registration with a for-hire endorsement must affirm liability coverage and knowledge of applicable United States Coast Guard safety requirements.

(c) The annual fee for a commercial fishing vessel registration shall be determined by the length of the vessel and shall be in addition to the fee for other licenses issued under this Article. The length of a vessel shall be determined by measuring the distance between the ends of the vessel along the deck and through the cabin, excluding the sheer. The annual fee for a commercial fishing vessel registration is:

(1) ~~One dollar ($1.00)~~One dollar and twenty-five cents ($1.25) per foot for a vessel not over 18 feet in length.

(2) ~~One dollar and fifty cents ($1.50)~~One dollar and ninety cents ($1.90) per foot for a vessel over 18 feet but not over 38 feet in length.

(3) ~~Three dollars ($3.00)~~Three dollars and seventy-five cents ($3.75) per foot for a vessel over 38 feet but not over 50 feet in length.

(4) ~~Six dollars ($6.00)~~Seven dollars and fifty cents ($7.50) per foot for a vessel over 50 feet in length.

(d) A vessel may be registered at any office of the Division. A commercial fishing vessel registration expires on the last day of the license year.

(e) Within 30 days of the date on which the owner of a registered vessel transfers ownership of the vessel, the new owner of the vessel shall notify the Division of the change in ownership and apply for a replacement commercial fishing vessel registration. An application for a replacement commercial fishing vessel registration shall be accompanied by proof of the transfer of the vessel. The provisions of G.S. 113-168.1(h) apply to a replacement commercial fishing vessel registration."

. . .

SECTION 14.8.(n) G.S. 113-174(2a) reads as rewritten:

"(2a) "For Hire ~~Boat~~"Vessel" means a charter boat, head boat, dive boat, or other ~~boat~~ vessel hired to allow individuals to engage in recreational fishing."

SECTION 14.8.(o) G.S. 113-174.3 reads as rewritten:

"**§ 113-174.3. For Hire Blanket CRFL.For-Hire Licenses.**

~~(a) License. – A person who operates a for hire boat may purchase a For Hire Blanket CRFL issued by the Division for the for hire boat. A For Hire Blanket CRFL authorizes all individuals on the for hire boat who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. A For Hire Blanket CRFL does not authorize individuals to engage in recreational fishing in joint fishing waters or inland fishing waters. A For Hire Blanket CRFL is valid for a period of one year from the date of issuance. The fee for a For Hire Blanket CRFL is:~~

~~(1) Two hundred fifty dollars ($250.00) for a vessel that will carry six or fewer passengers.~~

~~(2) Three hundred fifty dollars ($350.00) for a vessel that will carry greater than six passengers.~~

~~(b) Implementation. Except as provided in this section and G.S. 113-174.2(d), each individual on board a for hire boat engaged in recreational fishing, other than crew members who do not engage in recreational fishing, must hold a license issued under this Article or Article 25A of this Chapter. An owner, operator, or crew member of a for hire boat is not responsible for the licensure of a customer fishing from the boat.~~

(c) License. – It is unlawful for a person to engage in a for-hire operation without having obtained one of the following licenses issued by the Division:

(1) Blanket For-Hire Captain's CRFL. – This license allows individuals properly licensed by the United States Coast Guard to carry passengers on any vessel with a commercial vessel registration with a for-hire endorsement. A Blanket For-Hire Captain's CRFL authorizes all individuals on the for-hire vessel who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. The resident fees for a Blanket For-Hire Captain's CRFL are two hundred fifty dollars ($250.00) for a vessel carrying six or fewer passengers and three hundred fifty dollars ($350.00) for a vessel carrying more than six passengers. The nonresident fees for a Blanket For-Hire Captain's CRFL are three hundred twelve dollars and fifty cents ($312.50) for a vessel carrying six or fewer passengers and four hundred thirty-seven dollars and fifty cents ($437.50) for a vessel carrying more than six passengers. Any vessel whose operator is licensed under this subdivision and that is engaged in for-hire fishing must obtain a Commercial Fishing Vessel Registration with a for-hire endorsement.

(2) Blanket For-Hire Vessel CRFL. – This license allows any United States Coast Guard licensed operator to carry passengers aboard the licensed vessel. A Blanket For-Hire Vessel CRFL authorizes all individuals on the for-hire vessel who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. The resident fees for a Blanket For-Hire Vessel CRFL are two hundred fifty dollars ($250.00) for a vessel carrying six or fewer passengers and three hundred fifty dollars ($350.00) for a vessel carrying more than six passengers. The nonresident fees for a Blanket For-Hire Vessel CRFL are three hundred twelve dollars and fifty cents ($312.50) for a vessel carrying six or fewer passengers and four hundred thirty-seven dollars and fifty cents ($437.50) for a vessel carrying more than six passengers. Any vessel whose operator is licensed under this subdivision and that is engaged in for-hire fishing is not required to obtain a Commercial Fishing Vessel Registration with a for-hire endorsement.

(3) Non-Blanket For-Hire Vessel License. – This license allows any United States Coast Guard licensed operator to carry passengers aboard the licensed vessel. This license does not authorize individuals aboard the vessel to engage in recreational fishing unless they hold an individual CRFL issued under this Article or Article 25A of this Chapter. The fee for the Non-Blanket For-Hire Vessel License is twenty-five dollars ($25.00) for a vessel operated by a resident operator and thirty-seven dollars and fifty cents ($37.50) for a vessel operated by a nonresident operator. Any vessel whose operator is licensed under this subdivision and that is engaged in for-hire fishing is not required to obtain a Commercial Fishing Vessel Registration with a for-hire endorsement.

(d) A license issued under this section does not authorize individuals to engage in recreational fishing in joint fishing waters or inland fishing waters. All for-hire licenses expire on the last day of the license year.
(e) Each individual who obtains a for-hire license shall submit to the Division logbooks summarizing catch and effort statistical data to the Division. The Commission may adopt rules that determine the means and methods to satisfy the requirements of this subsection."

. . .

Appendix III Current Statutes Text:

§ 113-168.6. Commercial fishing vessel registration.

(a) As used in this subsection, a North Carolina vessel is a vessel that has its primary situs in the State. A vessel has its primary situs in the State if:

(1) A certificate of number has been issued for the vessel under Article 1 of Chapter 75A of the General Statutes;

(2) A certificate of title has been issued for the vessel under Article 4 of Chapter 75A of the General Statutes; or

(3) A certification of documentation has been issued for the vessel that lists a home port in the State under 46 U.S.C. § 12101, et seq., as amended.

(b) The owner of a vessel used in a commercial fishing operation in the coastal fishing waters of the State or a North Carolina vessel used to land or sell fish in the State shall register the vessel with the Division. It is unlawful to use a vessel that is not registered with the Division in a commercial fishing operation in the coastal fishing waters of the State. It is unlawful to use a North Carolina vessel that is not registered with the Division to land or sell fish in the State. No registration is required for a vessel of any length that does not have a motor if the vessel is used only in connection with another vessel that is properly registered.

(b1) The vessel owner at the time of application for registration under subsection (b) of this section shall obtain either a commercial vessel endorsement if the vessel is intended to be used primarily for the harvest of fish for sale, a for-hire endorsement if the vessel is intended to be used primarily for for-hire activities, or both endorsements if the vessel is intended to be engaged in both activities. The owner of a vessel applying for a commercial fishing vessel registration with a for-hire endorsement must affirm liability coverage and knowledge of applicable United States Coast Guard safety requirements.

(c) The annual fee for a commercial fishing vessel registration shall be determined by the length of the vessel and shall be in addition to the fee for other licenses issued under this Article. The length of a vessel shall be determined by measuring the distance between the ends of the vessel along the deck and through the cabin, excluding the sheer. The annual fee for a commercial fishing vessel registration is:

(1) One dollar and twenty-five cents ($1.25) per foot for a vessel not over 18 feet in length.

(2) One dollar and ninety cents ($1.90) per foot for a vessel over 18 feet but not over 38 feet in length.

(3) Three dollars and seventy-five cents ($3.75) per foot for a vessel over 38 feet but not over 50 feet in length.

(4) Seven dollars and fifty cents ($7.50) per foot for a vessel over 50 feet in length.

(d) A vessel may be registered at any office of the Division. A commercial fishing vessel registration expires on the last day of the license year.

(e) Within 30 days of the date on which the owner of a registered vessel transfers ownership of the vessel, the new owner of the vessel shall notify the Division of the change in ownership and apply for a replacement commercial fishing vessel registration. An application for a replacement commercial fishing vessel registration shall be accompanied by proof of the transfer of the vessel. The provisions of G.S. 113-168.1(h) apply to a replacement commercial fishing vessel registration. (1998-225, s. 4.15; 2001-213, s. 3; 2013-360, s. 14.8(e).)

§ 113-174.3. For-Hire Licenses.

(a), (b) Repealed by Session Laws 2013-360, s. 14.8(o), effective August 1, 2013.

(c) License. – It is unlawful for a person to engage in a for-hire operation without having obtained one of the following licenses issued by the Division:

(1) Blanket For-Hire Captain's CRFL. – This license allows individuals properly licensed by the United States Coast Guard to carry passengers on any vessel with a commercial vessel registration with a for-hire endorsement. A Blanket For-Hire Captain's CRFL authorizes all individuals on the for-hire vessel who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. The resident fees for a Blanket For-Hire Captain's CRFL are two hundred fifty dollars ($250.00) for a vessel carrying six or fewer passengers and three hundred fifty dollars ($350.00) for a vessel carrying more than six passengers. The nonresident fees for a Blanket For-Hire Captain's CRFL are three hundred twelve dollars and fifty cents ($312.50) for a vessel carrying six or fewer passengers and four hundred thirty-seven dollars and fifty cents ($437.50) for a vessel carrying more than six passengers. Any vessel whose operator is licensed under this subdivision and that is engaged in for-hire fishing must obtain a Commercial Fishing Vessel Registration with a for-hire endorsement.

(2) Blanket For-Hire Vessel CRFL. – This license allows any United States Coast Guard licensed operator to carry passengers aboard the licensed vessel. A Blanket For-Hire Vessel CRFL authorizes all individuals on the for-hire vessel who do not hold a license issued under this Article or Article 25A of this Chapter to engage in recreational fishing in coastal fishing waters that are not joint fishing waters. The resident fees for a Blanket For-Hire Vessel CRFL are two hundred fifty dollars ($250.00) for a vessel carrying six or fewer passengers and three hundred fifty dollars ($350.00) for a vessel carrying more than six passengers. The nonresident fees for a Blanket For-Hire Vessel CRFL are three hundred twelve dollars and fifty cents ($312.50) for a vessel carrying six or fewer passengers and four hundred thirty-seven dollars and fifty cents ($437.50) for a vessel carrying more than six passengers. Any vessel whose operator is licensed under this subdivision and that is engaged in for-hire fishing is not required to obtain a Commercial Fishing Vessel Registration with a for-hire endorsement.

(3) Non-Blanket For-Hire Vessel License. – This license allows any United States Coast Guard licensed operator to carry passengers aboard the licensed vessel. This license does not authorize individuals aboard the vessel to engage in recreational fishing unless they hold an individual CRFL issued under this Article or Article 25A of this Chapter. The fee for the Non-Blanket For-Hire Vessel License is twenty-five dollars ($25.00) for a vessel operated by a resident operator and thirty-seven dollars and fifty cents ($37.50) for a vessel operated by a nonresident operator. Any vessel whose operator is licensed under this subdivision and that is engaged in for-hire fishing is not required to obtain a Commercial Fishing Vessel Registration with a for-hire endorsement.

(d) A license issued under this section does not authorize individuals to engage in recreational fishing in joint fishing waters or inland fishing waters. All for-hire licenses expire on the last day of the license year.

(e) Repealed by Session Laws 2015-201, s. 1, effective August 5, 2015. (2005-455, s. 1.5; 2006-255, s. 7; 2006-259, s. 20.5; 2013-360, s. 14.8(o); 2015-201, s. 1.)

N.C. MARINE FISHERIES COMMISSION REGULATORY IMPACT ANALYSIS FOR READOPTION OF A PORTION OF RULES IN 15A NCAC 03I, 03J, 03K, 03L, 03M, 03O, AND 03R

Rule Readoptions:	15A NCAC 03I .0120, 03J .0101, .0102, .0108, .0203, .0204, .0206, .0207, .0209, .0303, .0304, 03K .0402-.0405, .0501-.0504, .0507, .0508, 03L .0208, 03M .0101-.0103, .0501, .0502, .0506, .0507, .0510, .0513, .0515, .0517, .0518, .0520, .0521, 03O .0106, .0501, .0503, 03R .0112
Name of Commission:	N.C. Marine Fisheries Commission
Agency Contact:	Catherine Blum, Rule Making Coordinator N.C. Division of Marine Fisheries 3441 Arendell Street Morehead City, NC 28557 (252) 808-8014 catherine.blum@ncdenr.gov
Analyst Contact:	Adam Stemle, Fisheries Economics Program Manager N.C. Division of Marine Fisheries 3441 Arendell Street Morehead City, NC 28557 (252) 808-8107 adam.stemle@ncdenr.gov
Impact Summary:	State government: No Local government: No Federal government: No Substantial impact: No
Authority:	G.S. 113-134; 113-168.6; 113-169.1; 113-169.2; 113-169.3; 113-169.4; 113-170; 113-170.4; 113-170.5; 113-173; 113-174.1; 113-182; 113-182.1; 113-185; 113-201; 113-202; 113-210; 113-221.1; 113-252; 143B-289.52
Necessity:	The proposed amendments readopt a portion of rules in 15A NCAC 03I .0100; 03J .0100, .0200, .0300; 03K .0400, .0500; 03L .0200; 03M .0100, .0500; 03O .0100, .0500; and 03R .0100 pursuant to requirements of G.S. 150B-21.3A.

I. Summary

The purpose of this document is to provide a regulatory impact analysis addressing any fiscal impacts associated with the readoption of a portion of rules in 15A NCAC 03I .0100; 03J .0100, .0200, .0300; 03K .0400, .0500; 03L .0200; 03M .0100, .0500; 03O .0100, .0500; and 03R .0100. These rules have been reviewed to conform to the requirements of G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules. The proposed readoptions consist of amendments that are of an administrative nature to update the 40 rules. Overall, the proposed readoptions do not result in a significant economic impact to the regulated community, state government, or other parties.

II. Introduction and Purpose of Rule Change(s)

The purpose of the Marine Fisheries Commission is to manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources within its jurisdiction, as described in G.S. 113-132, including commercial and recreational fisheries resources (Chapter 143B, Article 7, Part 5D). N.C. General Statute §150B-21.3A, adopted in 2013, requires state agencies to review existing rules every 10 years. Following an initial review, rules will be reviewed on a 10-year review cycle. The initial review comment period on all rules in 15A NCAC 03[1] was held from Feb. 23 - May 3, 2017; no public comments were received. The Marine Fisheries Commission subsequently approved the report on the review of the rules Aug. 16, 2017. The final report for rules in 15A NCAC 03 was reviewed and approved by the Rules Review Commission at its Dec. 14, 2017 meeting. The reports were forwarded to the Joint Legislative Administrative Procedure Oversight Committee for final determination. The committee met Jan. 9, 2018, completing the review process for these rules.

The final determinations were unchanged from how they were originally submitted. As a result, three rules were determined to be unnecessary and were expired from the N.C. Administrative Code, 36 rules were determined to be necessary without substantive public interest and remain in effect without further action, and 163 rules were determined to be necessary with substantive public interest and must be readopted as though they were new rules. This document addresses the first group of rules being considered for readoption.

III. Discussion

While proposed readoptions consist of amendments that are of an administrative nature, a few of the changes warrant additional explanation. A review of rule 15A NCAC 03O .0501 showed a need to consistently address the eligibility to apply for specific permits by the holder of an assigned Standard Commercial Fishing License. The current rule overtly states the eligibility for certain permits, but is silent about others. After conducting a review of procedures and eligibility for all permits, staff identified only one permit for which the holder of an assigned Standard Commercial Fishing License is not eligible: a Pound Net Set Permit (Appendix I, pg. 15). Proposed changes to the rule clearly state this eligibility status.

Rule 15A NCAC 03O .0503 currently includes the requirements for the Albemarle Sound Management Area River Herring Dealer Permit. To purchase river herring, a dealer must obtain an Albemarle Sound Management Area River Herring Dealer Permit (Appendix I, pg. 17). The permit conditions require the dealer to report landings daily to the Division and allow biological sampling of catches by Division personnel. But, Rule 15A NCAC 03M .0513 states it is unlawful to take or possess river herring from North Carolina Coastal Fishing Waters. This rule reflects the moratorium on the harvest of river herring put in place by the 2007 North Carolina River Herring Fishery Management Plan Amendment 1 that became effective in 2008. This was a result of the Division's 2005 stock assessment of river herring that determined river herring were overfished and overfishing was occurring, there was minimal recruitment with continued declines in abundance, and high fishing mortality rates. The only exception to the moratorium was a limited discretionary harvest for collection of biological data that occurred in conjunction with the Easter holiday

[1] A public comment period on the report for rules in 15A NCAC 03Q .0100 was held separately, from April 25-July 5, 2017, in conjunction with a similar public comment period held from May 22-July 31, 2017 on the report for rules in 15A NCAC 10C .0100 that are under the authority of the Wildlife Resources Commission. Both sets of rules are substantively identical and were jointly adopted by both agencies. These rules will be jointly readopted by both agencies at a future date.

weekend to provide product to local herring festivals. Even this harvest was discontinued after the 2014 discretionary season due to lack of compliance with the season's stated intent, in accordance with the 2015 North Carolina River Herring Fishery Management Plan Amendment 2.

Since 2014, there has been no harvest of river herring allowed. The rebuilding timeframe for the river herring population was projected to exceed 10 years from the date of the 2008 moratorium. As of 2018, the moratorium continues and the river herring stock is depleted, based on the results of the 2012 Atlantic States Marine Fisheries Commission Atlantic coastwide stock assessment of river herring. The stock assessment found that, although the North Carolina stock in the Albemarle Sound was not experiencing overfishing due to the harvest moratorium, it remained overfished. Since the Albemarle Sound Management Area River Herring Dealer Permit still exists in rule and all Division permits are issued free of charge, there is a small number of these permits that has continued to be issued (six to eight per year); however, the permits have not "permitted" the harvest, possession, purchase, or sale of river herring. The permit is obsolete and is proposed to be deleted from Rule 15A NCAC 03O .0503.

Rule 15A NCAC 03O .0503 also currently includes the requirements for the Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean (Appendix I, pg. 20). The rule provides that it is unlawful to trawl for shrimp in the Atlantic Ocean without a Turtle Excluder Device (TED) installed in trawls within one nautical mile of the shore from Browns Inlet to Rich's Inlet (an area approximately 30 nautical miles in length) without this permit when allowed by proclamation from April 1 through November 30. The purpose of the permit is to allow fishing activity to continue when concentrations of algae are found that would prevent fishing from occurring with a TED installed; the gear becomes so clogged with algae that fishing is nearly impossible. In lieu of using a TED, fishermen were required to limit their tow times to minimize impacts to sea turtles. In order for a proclamation to be issued so that the permit can be issued, a Section 10 Incidental Take Permit (ITP) under the Endangered Species Act must be in place from the National Oceanic and Atmospheric Administration Fisheries. An ITP allows a limited number of "takes" of a protected or endangered species, in this case sea turtles, with requirements to comply with specific permit conditions. Currently, there is not an ITP in place, thus there is insufficient authority in place to issue the proclamation that would enable a Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean to be issued.

From 2001-2005, there was an annual average number of 16 permits issued. This was the last five-year period for which the Division submitted an ITP application to the National Oceanic and Atmospheric Administration Fisheries in support of this permit. The algae has not returned to this area, but if it appeared in the future, a separate effort would have to be undertaken to seek an ITP and then address any rulemaking or permitting needs. There is no way to foresee when, where, or if algae would return and become an issue to address in this or any other fishery. The permit is obsolete and is proposed to be deleted from Rule 15A NCAC 03O .0503.

Finally, there are additional proposed amendments to the rules to make other minor technical and conforming changes. These include alphabetizing permits, using consistent language to refer to the Division of Marine Fisheries, and making other minor technical changes for proper punctuation and capitalization.

IV. Benefits

While there are no quantifiable economic benefits from the proposed rule amendments and readoptions, the public and law enforcement will benefit from clarity and consistency across rules.

V. Costs

There are no new anticipated costs to either the state government or regulated community associated with the proposed rule amendments and readoptions, as rule changes reflect current management practices.

Appendix I: Proposed Rule Readoptions

15A NCAC 03I .0120 POSSESSION OR TRANSPORTATION LIMITS

(a) It is unlawful to possess any species of fish ~~which~~ that is subject to ~~size~~ season, size, or harvest restrictions, while ~~actively~~ engaged in a fishing operation, unless all fish taken are in compliance with the restrictions for the waterbody and area being fished. If State season, size, or harvest restrictions that implement or comply with a fishery management plan adopted by the Atlantic States Marine Fisheries Commission, in accordance with G.S. 113-252, or adopted by the United States Secretary of Commerce pursuant to the Magnuson-Stevens Fishery Conservation and Management Act, 16 U.S.C. 1801, et seq. as amended, differ from regulations adopted by these entities, or if there are no federal regulations, the State restrictions shall apply. Nothing provided here is intended to supersede or interrupt the process to address State restrictions that do not implement or comply with a fishery management plan as described in this Paragraph. This process is found in the N.C. Fishery Management Plan for Interjurisdictional Fisheries available at http://portal.ncdenr.org/web/mf/nc-fisheries-management.

(b) It is unlawful to import into the ~~state~~ State species of fish native to North Carolina for sale in North Carolina that do not meet ~~established~~ size ~~limits,~~ limits established by rule or proclamation, except as provided in ~~15A NCAC~~ Rules 03K ~~.0202(c),~~ .0202, ~~03K~~ .0207, ~~03K~~ and .0305, and 03M ~~.0503.~~ .0503 of this Chapter.

Authority G.S. 113-134; 113-170; 113-170.4; 113-170.5; 113-182; 113-182.1; 113-252; 143B-289.52

15A NCAC 03J .0102 NETS OR NET STAKES

It is unlawful to use nets or net stakes:

(1) ~~Within~~ within 150 yards of any railroad or highway bridge crossing the Northeast Cape Fear River, New River, White Oak River, Trent River, Neuse River, Pamlico River, Roanoke River, and Alligator ~~River;~~River.

(2) ~~Within~~ within 300 yards of any highway bridge crossing Albemarle Sound, Chowan River, Croatan Sound, Currituck ~~Sound~~ Sound, and Roanoke ~~Sound;~~Sound.

(3) ~~If~~ if such net stakes are of metallic material.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0108 NETS PULLED BY MORE THAN ONE ~~BOAT~~ VESSEL

It is unlawful to pull or tow a net with more than one ~~boat~~ vessel, except in ~~long-haul fishing~~ long haul operations.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0203 CHOWAN RIVER AND ITS TRIBUTARIES

(a) In the Chowan River and its ~~tributaries:~~tributaries, it is unlawful to:

(1) ~~It is unlawful to~~ anchor the lead line of any net closer than 50 feet from ~~shore~~ shore, except in the Meherrin River.

~~(2) It is unlawful to use pound nets in any tributary creek or within 150 yards of the mouth of any such tributary creek of the Chowan River.~~

~~(3)~~(2) ~~It is unlawful to~~ set a pound net within 200 yards parallel to any other pound net in the Chowan River.

~~(4) It is unlawful to use a seine within 1,000 yards of the mouth of any creek tributary to the Chowan River.~~

~~(5)~~(3) ~~It is unlawful to~~ set a trotline within 100 yards of a pound net from February 1 through May 31.

(b) It is unlawful to set a pound net in any tributary of the Chowan River or within 150 yards of the mouth of any tributary of the Chowan River.

(c) It is unlawful to use a seine within 1,000 yards of the mouth of any tributary of the Chowan River.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0204 CURRITUCK SOUND AND ITS TRIBUTARIES
In Currituck Sound and its ~~tributaries:~~tributaries, it is unlawful to use a seine:

(1) ~~It is unlawful to use any net or seine with more than one power boat.~~in long haul operations.
(2) ~~It is unlawful to use any seine or haul net which~~ that is more than 900 yards in length or ~~which~~ that has a mesh length of less than three inches.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0206 SOUTHPORT BOAT HARBOR
It is unlawful to use any commercial fishing gear in the Southport Boat Harbor, Brunswick County, north of a line beginning at a point on the west side of the mouth of the harbor ~~33°54.9656'N – 78°01.4477' W~~ 33° 54.9656' N – 78° 01.4477' W running easterly to a point on the east side of the mouth of the harbor ~~33°54.9656'N – 78°01.3797' W.~~33° 54.9656' N – 78° 01.3797' W.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0207 ~~DUKE ENERGY PROGRESS BRUNSWICK~~ NUCLEAR PLANT INTAKE CANAL
It is unlawful to use any commercial fishing equipment in ~~the Duke Energy Progress Brunswick Nuclear Plant Intake Canal~~ a nuclear plant intake canal between the fish diversion screen and the ~~Duke Energy Progress Brunswick Nuclear Plant.~~nuclear plant.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0209 ALBEMARLE ~~SOUND/CHOWAN~~ SOUND AND CHOWAN RIVER RIVER HERRING MANAGEMENT AREAS
It is unlawful to use drift gill nets with a mesh length less than three inches from January 1 through May 15 in the Albemarle Sound and Chowan River river herring management areas defined in ~~15A NCAC 03R .0202.~~Rule 03R .0202 of this Chapter.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0303 DREDGES AND MECHANICAL METHODS PROHIBITED
(a) It is unlawful to use any dredge weighing more than 100 ~~pounds~~ pounds, except in the Atlantic Ocean.
(b) It is unlawful to use more than one dredge per vessel to take oysters or crabs or to use any dredges or mechanical methods between sunset and sunrise.
(c) It is unlawful to possess oysters aboard a vessel with a dredge weighing more than 100 pounds on board.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0304 ELECTRICAL FISHING DEVICE IN CAPE FEAR RIVER
It is unlawful to take catfish by the use of a hand-operated device generating pulsating electrical current in the Cape Fear River ~~except~~ except:

(1) from 800 feet downstream of Lock and Dam No. 1 in Bladen County to where the Black River joins the Cape Fear ~~River~~ River; and
(2) from July 1 through ~~the last day of February.~~March 1.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03J .0306 ~~HOOK-AND-LINE~~ HOOK AND LINE
It is unlawful to use any hook larger than 4/0 from July 1 through September 30 in the ~~internal coastal fishing waters~~ Internal Coastal Waters of Pamlico Sound and its tributaries south of the Albemarle Sound Management Area as defined in ~~15A NCAC~~ Rule 03R .0201 of this Chapter and north of a line beginning at a point 34° 59.7942' N - 76° 14.6514' W on Camp Point; running easterly to a point 34° 58.7853' N - 76° 09.8922' W on Core Banks while using natural bait from 7:00 p.m. to 7:00 a.m. unless the terminal tackle consists of:

(1) ~~A circle hook~~ a "circle hook", defined for the purpose of this Rule as a hook with the point of the hook directed perpendicularly back toward the ~~shank,~~ shank and with the barb either compressed or removed; and

(2) ~~A~~ a fixed sinker not less than two ounces in weight, secured not more than six inches from the fixed weight to the circle hook.

Authority G.S. 113-134; 113-182; ~~113-182.1;~~ 143B-289.52

15A NCAC 03K .0402 ~~SEASON,~~ SIZE AND HARVEST LIMITS

Size and harvest limits applicable to hard clams in ~~15A NCAC 03K~~ Rule .0301 of this Subchapter do not apply to Rangia clams.

Authority G.S. 113-134; 113-182; 113-201; 113-202; 143B-289.52

15A NCAC 03K .0403 DISPOSITION OF MEATS

It is unlawful to dispose of meats from Rangia clams taken ~~in~~ from prohibited (polluted) waters ~~for~~ by a method that will result in human consumption or ~~by a method that will~~ create risk of human consumption.

Authority G.S. 113-134; 113-182; 113-201; 113-202; 143B-298.52

15A NCAC 03K .0404 ~~DREDGES/MECHANICAL~~ DREDGES AND MECHANICAL METHODS PROHIBITED AND OPEN SEASON

It is unlawful to use mechanical methods for oystering or clamming to take Rangia clams or their shells:

(1) within 100 feet of any pier;

(2) within any established bed of submerged aquatic vegetation as defined in ~~15A NCAC~~ Rule 03I .0101 of this Chapter or salt water cordgrass (Spartina alterniflora) that may exist together or separately;

(3) in areas designated in ~~15A NCAC 03R .0108,~~ Rule 03R .0108 of this Chapter, except on shellfish leases and franchises with a Permit to Use Mechanical Methods for ~~Oysters and Clams~~ Shellfish on Shellfish Leases and Franchises.

(4) in areas designated in ~~15A NCAC 03K .0204(3) and 03R .0103;~~ Rule .0204 of this Subchapter and 03R .0103 of this Chapter; and

(5) except in areas and at times specified by proclamation as authorized by ~~15A NCAC 03K .0201 and 03K .0302.~~ Rules .0201 and .0302 of this Subchapter.

Authority G.S. 113-134; 113-182; 113-201; 143B-289.52

15A NCAC 03K .0405 OYSTERS, ~~MUSSELS,~~ HARD ~~CLAMS~~ CLAMS, OR MUSSELS PROHIBITED

~~While taking Rangia clams or their shells from a prohibited (polluted) area it~~ It is unlawful to possess ~~any other shellfish.~~ oysters, hard clams, or mussels while taking Rangia clams or their shells from a prohibited (polluted) area.

Authority G.S. 113-134; 113-182; 113-201; 143B-289.52

15A NCAC 03K .0501 BAY SCALLOP HARVEST MANAGEMENT

The Fisheries Director may, by proclamation, impose any or all of the following restrictions ~~for commercial or recreational~~ on the taking of bay ~~scallop harvest~~ scallops from public bottom:

(1) specify time;

(2) specify area;

(3) specify means and methods;

(4) specify open seasons for the taking of bay scallops during the period beginning the last Monday in January and ending the last Friday in May;

(5) specify size; and

(6) specify quantity, but shall not exceed possession of more than 15 standard U.S. bushels per person per day or a total of 30 standard U.S. bushels in any combined commercial fishing operation per day.

Authority G.S. 113-134; 113-182; 113-201; 113-221.1; 143B-289.52

15A NCAC 03K .0502 TAKING BAY SCALLOPS AT NIGHT AND ON WEEKENDS
(a) It is unlawful to take bay scallops between sunset and sunrise, or on Saturdays or Sundays, except as provided in ~~15A NCAC 03K .0105.~~Rule .0105 of this Subchapter.
(b) Bay scallops taken on Saturdays or Sundays from shellfish leases or franchises in accordance with G.S. 113-208 are exempt from this Rule.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03K .0503 ~~PROHIBITED~~ BAY SCALLOP DREDGE PROHIBITED
It is unlawful to take bay scallops with dredges weighing more than 50 pounds or equipped with teeth. Any other instrument or device designed to drag the bottom to aid in the taking of bay scallops is also prohibited.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03K .0504 CALICO SCALLOP ~~SEASON~~ HARVEST MANAGEMENT
(a) It is unlawful to land or possess aboard a vessel calico scallops ~~except~~ except, at such times as designated by the Fisheries Director by proclamation.
(b) The Fisheries Director may, be proclamation, impose any or all of the following restrictions on the taking of calico scallops:
(1) specify time;
(2) specify area;
(3) specify means and methods;
(4) specify season;
(5) specify size; and
(6) specify quantity.

Authority G.S. 113-134; 113-182; ~~113-221;~~ 113-221.1; 143B-289.52

15A NCAC 03K .0507 MARKETING SCALLOPS TAKEN FROM SHELLFISH LEASES OR FRANCHISES
(a) It is unlawful to sell, purchase, or possess scallops during the closed season without the lease or franchise holder delivering to the purchaser or other recipient a certification, on a form provided by the ~~Division,~~ Division of Marine Fisheries, that the scallops were taken from a valid shellfish lease or franchise. Certification forms shall be furnished by the Division to lease and franchise holders upon request.
(b) It is unlawful for lease or franchise holders or their designees to take or possess scallops from public bottom while possessing aboard a vessel scallops taken from shellfish leases or franchises.

Authority G.S. 113-134; 113-182; 113-201; 143B-289.52

15A NCAC 03K .0508 SCALLOP ~~SEASON AND~~ AQUACULTURE HARVEST ~~LIMIT~~ EXEMPTIONS
The following exemptions and restrictions shall apply to the possession, sale, purchase, or transport of scallops produced in an aquaculture operation:
(1) Possession and sale of scallops by a scallop aquaculture operation shall be exempt from restrictions set forth in ~~15A NCAC 03K~~ Rules .0501, .0504, and ~~.0505.~~.0505 of this Section.
(2) Purchase and possession of scallops from a scallop aquaculture operation shall be exempt from restrictions set forth in ~~15A NCAC 03K~~ Rules .0501, .0504, and ~~.0505.~~.0505 of this Section.

(3) It is unlawful for a person to possess, sell, purchase, or transport scallops described in Sub-Items (1) and (2) of this Rule unless in compliance with all conditions of the Aquaculture Operation ~~Permit, as set forth in 15A NCAC 03O .0501 and .0503.~~Permit set forth in 15A NCAC 03O Section .0500.

Authority G.S. 113-134; 113-182; 113-201; 143B-289.52

15A NCAC 03L .0208 STONE CRABS ~~(MENIPPE MERCENARIA)~~

~~It is unlawful to:~~

~~(1) Possess stone crab bodies, or fail to immediately return stone crab bodies to the waters from which taken;~~

~~(2) Remove, take or possess any claw(s) from June 15 through August 15;~~

~~(3) Remove, take or possess any claw(s) from egg-bearing stone crabs;~~

~~(4) Use any device to take stone crabs that can puncture, crush, or injure the crab body, such as gigs, spears, grabs, hooks, or similar devices; and~~

~~(5) Remove, take or possess stone crab claw(s) which have a propodus (forearm) less than two and three quarter inches in length, measured by a straight line from the elbow to the tip of the lower immovable finger. The propodus (forearm) is defined as the largest section of the claw assembly that has both a movable and immovable finger and is located farthest from the body of the crab.~~

(a) It is unlawful to possess stone crab bodies or fail to immediately return stone crab bodies to the waters from which taken.

(b) It is unlawful to remove, take, or possess any claw(s) from June 15 through August 15.

(c) It is unlawful to remove, take, or possess any claw(s) from egg-bearing stone crabs.

(d) It is unlawful to use any device to take stone crabs that can puncture, crush, or injure the crab body, such as gigs, spears, grabs, hooks, or similar devices.

(e) It is unlawful to remove, take, or possess stone crab claw(s) that have a propodus (forearm) less than 2 and ¾ inches in length, measured by a straight line from the elbow to the tip of the lower immovable finger. For the purpose of this Rule, "propodus" is defined as the largest section of the claw assembly that has both a movable and immovable finger and is located farthest from the body of the crab.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0101 is proposed for readoption with substantive changes as follows:

SUBCHAPTER 03M - FINFISH

SECTION .0100 – FINFISH, GENERAL

15A NCAC 03M .0101 MUTILATED FINFISH

It is unlawful to possess aboard a vessel or while engaged in fishing any species of finfish that is subject to a size or harvest restriction without having head and tail attached, except:

(1) mullet when used for bait;

(2) hickory shad when used for ~~bait~~ bait, provided that not more than two hickory shad per vessel or fishing operation may be cut for bait at any one time; and

(3) tuna possessed in a commercial fishing operation as provided in ~~15A NCAC 03M .0520.~~Rule .0520 of this Subchapter.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0102 is proposed for readoption with substantive changes as follows:

15A NCAC 03M .0102 UNMARKETABLE FINFISH

~~(a) It is unlawful to land finfish if in violation of minimum size or possession limits established by rule or proclamation.~~

~~(b)~~(a) It is unlawful to land ~~finfish~~ finfish, taken in connection with a commercial fishing ~~operations which~~ operation, that are unmarketable as individual finfish by reason of size, except a quantity not exceeding 5,000 pounds per vessel per day may be sold to a dealer that is licensed under G.S. 113-169.3(f)(6), ~~(7) and~~ (7), or (8).
~~(c)~~(b) ~~Menhaden,~~ Atlantic menhaden, Atlantic thread herring, gizzard shad, and pinfish are exempt from this Rule.

Authority G.S. 113-134; 113-182; 113-185; 143B-289.52
15A NCAC 03M .0103 is proposed for readoption with substantive changes as follows:

15A NCAC 03M .0103 MINIMUM SIZE LIMITS
It is unlawful to possess, sell, or purchase finfish under four inches in length except:

(1) bait in the crab pot fishery in North Carolina with the following provision: such crab pot bait shall not be transported west of U.S. Interstate 95 and when transported, shall be accompanied by documentation showing the name and address of the shipper, the name and address of the consignee, and the total weight of the shipment;
(2) bait in the finfish fishery with the following provisions:
   (a) ~~It~~ it is unlawful to possess more than 200 pounds of live finfish or 100 pounds of dead finfish; and
   (b) ~~Such~~ such finfish bait may not be transported outside ~~the State~~ of North Carolina;
(3) live finfish in aquaria, provided the finfish are not subject to other minimum size limits under the authority of Marine Fisheries Commission ~~Rule;~~ rules; and
(4) ~~menhaden, herring,~~ Atlantic menhaden, Atlantic thread herring, gizzard shad, and pinfish.

Bait dealers who possess a valid finfish dealer license from the Division of Marine Fisheries are exempt from Sub-Items (2)(a) and (b) of this Rule. Tolerance of not more than five percent by number of species shall be allowed.

Authority G.S. 113-134; 113-182; 113-185; 143B-289.52

15A NCAC 03M .0501 RED DRUM
(a) It is unlawful to remove red drum from any type of net with the aid of any boat hook, gaff, spear, gig, or similar device.
(b) It is unlawful to take or possess red drum taken by any boat hook, gaff, spear, gig, or similar device.
(c) It is unlawful to possess red drum less than 18 inches total length or greater than 27 inches total length.
(d) It is unlawful to possess more than one red drum per person per day taken by ~~hook-and-line~~ hook and line or for recreational purposes.
(e) ~~The annual~~ Annual commercial harvest limit ~~(September 1 through August 31)~~ for red ~~drum~~ drum: ~~is 250,000 pounds. The annual commercial harvest limit is allotted in two periods: September 1 through April 30 at 150,000 pounds, and May 1 through August 31 at 100,000 pounds plus any remainder from the first period allotment. Any annual commercial harvest limit that is exceeded one year will result in the poundage overage being deducted from the subsequent year's commercial harvest limit and the Fisheries Director shall adjust the period allotments accordingly. If the harvest limit is projected to be taken in any period, the Fisheries Director shall, by proclamation, prohibit possession of red drum taken in a commercial fishing operation for the remainder of that period.~~

(1) The annual commercial harvest limit for red drum is 250,000 pounds.
(2) The annual commercial harvest limit for red drum is calculated from September 1 through August 31 and is allotted in two periods:
   (A) September 1 through April 30 at 150,000 pounds; and
   (B) May 1 through August 31 at 100,000 pounds plus any remainder from the first period allotment.
(3) If the harvest limit is projected to be taken in any period, the Fisheries Director shall, by proclamation, prohibit possession of red drum taken in a commercial fishing operation for the remainder of that period.

(4) Any commercial harvest limit that is exceeded one year shall result in the poundage overage being deducted from the subsequent year's commercial harvest limit and the Fisheries Director shall, by proclamation, adjust the period allotments as described in this Paragraph.

Authority G.S. 113-134; 113-182; ~~113-221;~~ 113-221.1; 143B-289.52

15A NCAC 03M .0502 MULLET

~~(a) The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:~~

~~(1) Specify season,~~
~~(2) Specify areas,~~
~~(3) Specify quantity,~~
~~(4) Specify means/methods,~~
~~(5) Specify size.~~

~~(b)~~(a) It is unlawful to possess more than 200 mullet per person per day for recreational purposes.

(b) The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of mullet:

(1) specify time;
(2) specify area;
(3) specify means and methods;
(4) specify season;
(5) specify size; and
(6) specify quantity, except as provided in Paragraph (a) of this Rule.

Authority G.S. 113-134; 113-182; ~~113-221;~~ 113-221.1; 143B-289.52

15A NCAC 03M .0506 ~~SNAPPER-GROUPER~~ SNAPPER GROUPER COMPLEX

(a) In the Atlantic Ocean, it is unlawful for an individual fishing under a Recreational Commercial Gear License with seines, shrimp trawls, pots, ~~trotlines~~ trotlines, or gill nets to take any species of the ~~Snapper-Grouper~~ snapper grouper complex.

(b) The species of the ~~snapper-grouper~~ snapper grouper complex listed in the South Atlantic Fishery Management Council Fishery Management Plan for the ~~Snapper-Grouper~~ Snapper Grouper Fishery of the South Atlantic Region are hereby incorporated by ~~reference and copies~~ reference. Copies of the plan are available ~~via the Federal Register posted on the Internet~~ at www.safmc.net and at the Division of Marine Fisheries, 3441 Arendell Street, P.O. Box 769, Morehead City, North Carolina ~~28557~~ 28557, at no cost.

Authority G.S. 113-134; 113-182; ~~113-221;~~ 143B-289.52

15A NCAC 03M .0507 BILLFISH

(a) It is unlawful to take blue marlin, white marlin, roundscale spearfish, or sailfish, except by hook and line or for recreational purposes.

~~(a)~~(b) ~~Marlin: Taken for recreational purposes or by hook and line:~~For blue marlin, white marlin, and roundscale spearfish, it is unlawful to:

(1) ~~It is unlawful to~~ possess blue marlin less than 99 inches in length from the lower jaw to the fork in the tail.
(2) ~~It is unlawful to~~ possess white marlin or roundscale spearfish less than 66 inches in length from the lower jaw to the fork in the tail.
(3) ~~It is unlawful to~~ possess more than one blue marlin, ~~or~~ white ~~marlin~~ marlin, or roundscale spearfish in the aggregate per vessel per trip.
(4) ~~It is unlawful to~~ sell or offer for sale blue marlin, ~~or~~ white ~~marlin.~~marlin, or roundscale spearfish.

~~(b)~~(c) ~~Sailfish: Taken for recreational purposes or by hook and line:~~For sailfish, it is unlawful to:

(1) ~~It is unlawful to~~ possess sailfish less than 63 inches in length from the lower jaw to the fork in the tail.
(2) ~~It is unlawful to~~ possess more than one sailfish per person per day.

(3) ~~It is unlawful to~~ sell or offer for sale sailfish.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0510 AMERICAN EEL

~~It is unlawful to:~~

~~(1) Possess, sell or take American eels less than nine inches in length;~~

~~(2) Possess more than 25 American eels per person per day for recreational purposes, except the master and each mate of for-hire vessels that hold a valid for-hire license may possess 50 eels each per day; and~~

~~(3) Possess American eels from September 1 through December 31 except when taken by baited pots.~~

(a) It is unlawful to possess, sell, or take American eels less than nine inches in length.

(b) It is unlawful to possess more than 25 American eels per person per day for recreational purposes, except the master and each mate of for-hire vessels that hold a valid for-hire license may possess 50 eels each per day.

(c) It is unlawful to possess American eels from September 1 through December 31, except when taken by baited pots.

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0513 RIVER HERRING

It is unlawful to take or possess river herring from North Carolina Coastal Fishing Waters. Possession of river herring from sources other than North Carolina Coastal Fishing Waters shall be limited to fish less than or equal to six inches total length when aboard a vessel or while engaged in fishing.

Authority G.S. 113-134; 113-182; ~~113-221;~~ 143B-289.52

15A NCAC 03M .0515 DOLPHIN

(a) It is unlawful to possess for recreational purposes:

(1) more than 10 dolphin per person per day taken by hook and ~~line for recreational purposes.~~line.

(2) more than 60 dolphin per vessel per day regardless of the number of individuals on board, except headboat vessels with a valid U.S. Coast Guard Certificate of Inspection may possess 10 dolphin per paying customer.

~~(b) It is unlawful to possess more than 60 dolphin per day per vessel regardless of the number of people on board, except headboat vessels with a valid U.S. Coast Guard Certificate of Inspection may possess 10 dolphin per paying customer.~~

~~(c)~~(b) It is unlawful ~~to take or possess~~ in a commercial fishing operation without a valid federal Atlantic Dolphin/Wahoo Commercial vessel permit:

(1) to take or possess more than 10 dolphin per person per ~~day, or~~ day.

(2) to sell dolphin.~~dolphin without a valid Federal Commercial Dolphin/Wahoo vessel permit and either a Standard Commercial Fishing License, a Retired Standard Commercial Fishing License, or a Land or Sell License.~~

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0517 WAHOO

(a) It is unlawful to possess for recreational purposes more than two wahoo per person per day taken by hook and ~~line for recreational purposes.~~line.

(b) It is unlawful in a commercial fishing operation:

(1) without a valid federal Atlantic Dolphin/Wahoo Commercial vessel permit:

(A) to take or possess more than two wahoo per person per ~~day, or~~ day.

(B) to sell wahoo.~~wahoo without a Federal Commercial Dolphin/Wahoo permit and either a Standard Commercial Fishing License, Retired Standard Commercial Fishing License, or a Land or Sell License.~~

(2) to possess aboard a vessel or land more than 500 pounds of wahoo per trip.

~~(c) It is unlawful to possess aboard or land more than 500 pounds of wahoo per trip in a commercial fishing operation.~~

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0518 ~~KINGFISH~~ KINGFISHES (SEA MULLET)

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of kingfishes:

- ~~(1) Specify season,~~
- ~~(2) Specify areas,~~
- ~~(3) Specify quantity,~~
- ~~(4) Specify means and methods,~~
- ~~(5) Specify size.~~
- (1) specify time;
- (2) specify area;
- (3) specify means and methods;
- (4) specify season;
- (5) specify size; and
- (6) specify quantity.

Authority G.S. 113-134; 113-182; ~~113-221; 143B-289.4~~113-221.1; 143B-289.52

15A NCAC 03M .0520 TUNA

(a) It is unlawful to possess for recreational purposes:

- (1) yellowfin tuna less than 27 inches curved fork length.
- (2) bigeye tuna less than 27 inches curved fork length.
- (3) more than three yellowfin tuna per person per day.

~~(a)~~(b) It is unlawful to possess in a commercial fishing operation:

- (1) ~~Yellowfin~~ yellowfin tuna less than 27 inches curved fork length or 27 inches from the fork of the tail to the forward edge of the cut of beheaded tuna.
- (2) ~~Bigeye~~ bigeye tuna less than 27 inches curved fork length or 27 inches from the fork of the tail to the forward edge of the cut of beheaded tuna.
- (3) ~~Bluefin~~ Atlantic bluefin tuna less than 73 inches curved fork length or 54 inches pectoral fin curved fork length.
- ~~(b)~~(4) ~~It is unlawful to possess in a commercial fishing operation tunas~~ tuna subject to a size or harvest restriction without having ~~tails~~ the tail attached.

~~(c) It is unlawful to possess for recreational purposes:~~

- ~~(1) Yellowfin tuna less than 27 inches curved fork length.~~
- ~~(2) Bigeye tuna less than 27 inches curved fork length.~~
- ~~(3) More than three yellowfin tuna per person per day.~~

Authority G.S. 113-134; 113-182; 143B-289.52

15A NCAC 03M .0521 SHEEPSHEAD

The Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of sheepshead:

- (1) specify time;
- (2) specify area;
- (3) specify means and methods;
- (4) specify season;
- (5) specify size; and
- (6) specify quantity.

Authority G.S. 113-134; 113-182; 113-221.1; 143B-289.52

15A NCAC 03O .0106 DISPLAY OF LICENSES AND REGISTRATIONS

(a) It is unlawful:

(1) ~~For~~ <u>for</u> any person to use a vessel required to be registered under the provisions of G.S. 113-168.6 in a commercial fishing operation without a current ~~commercial fishing vessel registration~~ <u>Commercial Fishing Vessel Registration</u> decal mounted on an exterior surface so as to be plainly visible when viewed from the port side; and

(2) ~~To~~ <u>to</u> display any ~~commercial fishing vessel registration~~ <u>Commercial Fishing Vessel Registration</u> decal not issued for the vessel displaying it.

(b) It is unlawful to fail to display ~~any fish dealer's licenses~~ <u>a Fish Dealer License</u> required by G.S. ~~113-169.3,~~ <u>113-169.3</u> or ~~ocean fishing pier license~~ <u>Ocean Fishing Pier License</u> required by G.S. 113-169.4 in prominent public view in each location subject to licensing.

(c) It is unlawful <u>for any person licensed under G.S. 113-174.3</u> to fail to display a current ~~For-Hire License~~ <u>for-hire vessel</u> decal on the exterior surface of the vessel so as to be visible when viewed from the port side while engaged in for-hire recreational fishing.

Authority G.S. <u>113-134;</u> 113-168.6; 113-169.3; 113-169.4; <u>113-174.1; 113-182;</u> 143B-289.52

15A NCAC 03O .0501 PROCEDURES AND REQUIREMENTS TO OBTAIN PERMITS

(a) To obtain any <u>Division of</u> Marine Fisheries permit, an applicant, responsible party, or person holding a power of attorney shall provide the following information:

(1) the full name, physical address, mailing address, date of birth, and signature of the applicant on the application and, if the applicant is not appearing before a license agent or the designated Division <u>of Marine Fisheries</u> contact, the applicant's signature on the application shall be notarized;

(2) a current picture identification of applicant, responsible party, or person holding a power of ~~attorney. Acceptable~~ <u>attorney, acceptable</u> forms of <u>which include</u> ~~picture identification are~~ driver's license, North Carolina Identification card issued by the North Carolina Division of Motor Vehicles, military identification card, resident alien card (green card), or passport, or if applying by mail, a copy thereof;

(3) for permits that require a list of designees, the full names and dates of birth of designees of the applicant who will be acting under the requested permit;

(4) certification that the applicant and his designees do not have four or more marine or estuarine resource convictions during the previous three years;

(5) for permit applications from business entities:

(A) the business name;

(B) the type of business entity: corporation, "educational institution" as defined in ~~15A NCAC 03I .0101,~~ <u>Rule 03I .0101 of this Chapter,</u> limited liability company (LLC), partnership, or sole proprietorship;

(C) the name, address, and phone number of responsible party and other identifying information required by this Subchapter or rules related to a specific permit;

(D) for a corporation applying for a permit in a corporate name, the current articles of incorporation and a current list of corporate officers;

(E) for a partnership that is established by a written partnership agreement, a current copy of such agreement shall be provided when applying for a permit; and

(F) for business entities other than corporations, copies of current assumed name statements if filed with the Register of Deeds office for the corresponding county and copies of current business privilege tax certificates, if applicable; and

(6) additional information as required for specific permits.

~~(b) A permittee shall hold a valid Standard or Retired Standard Commercial Fishing License in order to hold a:~~

~~(1) Pound Net Permit;~~

~~(2) Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean;~~

~~(3) Atlantic Ocean Striped Bass Commercial Gear Permit; or~~

~~(4) Permit for Weekend Trawling for Live Shrimp.~~

~~(A) An individual who is assigned a Standard Commercial Fishing License is the individual required to hold a Permit for Weekend Trawling for Live Shrimp.~~

~~(B) The master designated on the single vessel corporation Standard Commercial Fishing License is the individual required to hold the Permit for Weekend Trawling for Live Shrimp.~~

(b) A permittee shall hold a valid:

(1) Standard or Retired Standard Commercial Fishing License in order to hold:

(A) an Atlantic Ocean Striped Bass Commercial Gear Permit;

(B) a Permit for Weekend Trawling for Live Shrimp; or

(C) a Pound Net Set Permit.

The master designated on the single vessel corporation Standard Commercial Fishing License is the individual required to hold the Permit for Weekend Trawling for Live Shrimp.

(2) Fish Dealer License in the proper category in order to hold dealer permits for monitoring fisheries under a quota or allocation for that category.

(c) An individual who is assigned a valid Standard Commercial Fishing License with applicable endorsements is eligible to hold any permit that requires a Standard Commercial Fishing License except a Pound Net Set Permit.

~~(c)~~(d) If mechanical methods to take shellfish are used, a permittee and his designees shall hold a valid Standard or Retired Standard Commercial Fishing License with a Shellfish Endorsement in order for a permittee to hold a:

~~(1) Permit to Transplant Prohibited (Polluted) Shellfish;~~

~~(2) Permit to Transplant Oysters from Seed Oyster Management Areas;~~

~~(3) Permit to Use Mechanical Methods for Shellfish on Shellfish Leases or Franchises, except as provided in G.S. 113-169.2;~~

~~(4) Permit to Harvest Rangia Clams from Prohibited (Polluted) Areas; or~~

~~(5) Depuration Permit.~~

(1) Depuration Permit;

(2) Permit to Harvest Rangia Clams from Prohibited (Polluted) Areas;

(3) Permit to Transplant Oysters from Seed Oyster Management Areas;

(4) Permit to Transplant Prohibited (Polluted) Shellfish; or

(5) Permit to Use Mechanical Methods for Shellfish on Shellfish Leases or Franchises, except as provided in G.S. 113-169.2.

~~(d)~~(e) If mechanical methods to take shellfish are not used, a permittee and his designees shall hold a valid Standard or Retired Standard Commercial Fishing License with a Shellfish Endorsement or a Shellfish License in order for a permittee to hold a:

~~(1) Permit to Transplant Prohibited (Polluted) Shellfish;~~

~~(2) Permit to Transplant Oysters from Seed Oyster Management Areas;~~

~~(3) Permit to Harvest Rangia Clams from Prohibited (Polluted) Areas; or~~

~~(4) Depuration Permit.~~

(1) Depuration Permit;

(2) Permit to Harvest Rangia Clams from Prohibited (Polluted) Areas;

(3) Permit to Transplant Oysters from Seed Oyster Management Areas; or

(4) Permit to Transplant Prohibited (Polluted) Shellfish.

~~(e) A permittee shall hold a valid:~~

~~(1) Fish Dealer License in the proper category in order to hold Dealer Permits for Monitoring Fisheries Under a Quota/Allocation for that category; and~~

~~(2) Standard Commercial Fishing License with a Shellfish Endorsement, Retired Standard Commercial Fishing License with a Shellfish Endorsement, or a Shellfish License in order to harvest clams or oysters for depuration.~~

(f) ~~Aquaculture Operations/Collection Permits:~~Aquaculture Operation Permit and Aquaculture Collection Permit:

(1) A permittee shall hold a valid Aquaculture Operation Permit issued by the Fisheries Director to hold an Aquaculture Collection Permit.

(2) The permittee or designees shall hold appropriate licenses from the Division of Marine Fisheries for the species harvested and the gear used under the Aquaculture Collection Permit.

(g) Atlantic Ocean Striped Bass Commercial Gear Permit:

(1) An applicant for an Atlantic Ocean Striped Bass Commercial Gear Permit shall declare one of the following types of gear for an initial permit and at intervals of three consecutive license years thereafter:

(A) a gill net;

(B) a trawl net; or

(C) a beach seine.

For the purpose of this Rule, a "beach seine" is defined as a swipe net constructed of multi-filament or multi-fiber webbing fished from the ocean beach that is deployed from a vessel launched from the ocean beach where the fishing operation takes place. Gear declarations shall be binding on the permittee for three consecutive license years without regard to subsequent annual permit issuance.

(2) A person is not eligible for more than one Atlantic Ocean Striped Bass Commercial Gear Permit regardless of the number of Standard Commercial Fishing Licenses, Retired Standard Commercial Fishing Licenses, or assignments held by the person.

(h) Applications submitted without complete and required information shall not be processed until all required information has been submitted. Incomplete applications shall be returned to the applicant with the deficiency in the application noted.

(i) A permit shall be issued only after the application has been deemed complete by the Division of Marine Fisheries and the applicant certifies to abide by the permit general and specific conditions established under ~~15A NCAC~~ Rules 03J .0501, .0505, 03K .0103, .0104, .0107, .0111, .0401, 03O .0502, and ~~.0503,~~ .0503 of this Chapter, as applicable to the requested permit.

(j) In determining whether to issue, modify, or renew a permit, the Fisheries Director or his agent shall evaluate factors such as the following:

(1) potential threats to public health or marine and estuarine resources regulated by the Marine Fisheries Commission;

(2) the applicant's demonstration of a valid justification for the permit and a showing of responsibility; and

(3) the applicant's history of fisheries violations evidenced by eight or more violations in 10 years.

(k) The Division of Marine Fisheries shall notify the applicant in writing of the denial or modification of any permit request and the reasons therefor. The applicant may submit further information or reasons why the permit should not be denied or modified.

(l) Permits are valid from the date of issuance through the expiration date printed on the permit. Unless otherwise established by rule, the Fisheries Director may establish the issuance timeframe for specific types and categories of permits based on season, calendar year, or other period based upon the nature of the activity permitted, the duration of the activity, compliance with federal or state fishery management plans or implementing rules, conflicts with other fisheries or gear usage, or seasons for the species involved. The expiration date shall be specified on the permit.

(m) For permit renewals, the permittee's signature on the application shall certify all information as true and accurate. Notarized signatures on renewal applications shall not be required.

(n) It is unlawful for a permit holder to fail to notify the Division of Marine Fisheries within 30 days of a change of name or address, in accordance with G.S. 113-169.2.

(o) It is unlawful for a permit holder to fail to notify the Division of Marine Fisheries of a change of designee prior to use of the permit by that designee.

(p) Permit applications are available at all Division of Marine Fisheries offices.~~Offices.~~

Authority G.S. 113-134; 113-169.1; 113-169.2; 113-169.3; 113-182; 113-210; 143B-289.52

15A NCAC 03O .0503 PERMIT CONDITIONS; SPECIFIC

~~(a) Horseshoe Crab Biomedical Use Permit:~~

~~(1) It is unlawful to use horseshoe crabs for biomedical purposes without first obtaining a permit.~~

~~(2) It is unlawful for persons who have been issued a Horseshoe Crab Biomedical Use Permit to fail to submit an annual report on the use of horseshoe crabs to the Division of Marine Fisheries due on February 1 of each year. Such reports shall be filed on forms provided by the Division and shall include a monthly account of the number of crabs harvested,~~

~~statement of percent mortality up to the point of release, harvest method, number or percent of males and females, and disposition of bled crabs prior to release.~~

~~(3) It is unlawful for persons who have been issued a Horseshoe Crab Biomedical Use Permit to fail to comply with the Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan for Horseshoe Crab. The Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan for Horseshoe Crab is incorporated by reference including subsequent amendments and editions. Copies of this plan are available via the Internet from the Atlantic States Marine Fisheries Commission at http://www.asmfc.org/fisheries-management/program-overview and at the Division of Marine Fisheries, 3441 Arendell Street, P.O. Box 769, Morehead City, NC 28557 at no cost.~~

~~(b) Dealers Permits for Monitoring Fisheries under a Quota/Allocation:~~

~~(1) During the commercial season opened by proclamation or rule for the fishery for which a Dealers Permit for Monitoring Fisheries under a Quota/Allocation permit is issued, it is unlawful for the fish dealers issued such permit to fail to:~~

~~(A) fax or send via electronic mail by noon daily, on forms provided by the Division, the previous day's landings for the permitted fishery to the dealer contact designated on the permit. Landings for Fridays or Saturdays shall be submitted on the following Monday. If the dealer is unable to fax or electronic mail the required information, the permittee shall call in the previous day's landings to the dealer contact designated on the permit.~~

~~(B) submit the required form set forth in Subitem (b)(1)(A) of this Rule to the Division upon request or no later than five days after the close of the season for the fishery permitted;~~

~~(C) maintain faxes and other related documentation in accordance with 15A NCAC 03I .0114;~~

~~(D) contact the dealer contact designated on the permit daily regardless of whether or not a transaction for the fishery for which a dealer is permitted occurred; and~~

~~(E) record the permanent dealer identification number on the bill of lading or receipt for each transaction or shipment from the permitted fishery.~~

~~(2) Striped Bass Dealer Permit:~~

~~(A) It is unlawful for a fish dealer to possess, buy, sell, or offer for sale striped bass taken from the following areas without first obtaining a Striped Bass Dealer Permit validated for the applicable harvest area:~~

~~(i) Atlantic Ocean;~~

~~(ii) Albemarle Sound Management Area as designated in 15A NCAC 03R .0201; and~~

~~(iii) the Joint and Coastal Fishing Waters of the Central/Southern Management Area as designated in 15A NCAC 03R .0201.~~

~~(B) No permittee shall possess, buy, sell, or offer for sale striped bass taken from the harvest areas opened by proclamation without having a North Carolina Division of Marine Fisheries issued valid tag for the applicable area affixed through the mouth and gill cover, or, in the case of striped bass imported from other states, a similar tag that is issued for striped bass in the state of origin. North Carolina Division of Marine Fisheries striped bass tags shall not be bought, sold, offered for sale, or transferred. Tags shall be obtained at the North Carolina Division of Marine Fisheries Offices. The Division of Marine Fisheries shall specify the quantity of tags to be issued based on historical striped bass landings. It is unlawful for the permittee to fail to surrender unused tags to the Division upon request.~~

~~(3) Albemarle Sound Management Area for River Herring Dealer Permit: It is unlawful to possess, buy, sell, or offer for sale river herring taken from the Albemarle Sound Management Area for River Herring as defined in 15A NCAC 03R .0202 without first obtaining an Albemarle Sound Management Area for River Herring Dealer Permit.~~

~~(4) Atlantic Ocean Flounder Dealer Permit:~~

~~(A) It is unlawful for a fish dealer to allow vessels holding a valid License to Land Flounder from the Atlantic Ocean to land more than 100 pounds of flounder from a single transaction at their licensed location during the open season without first obtaining an Atlantic Ocean Flounder Dealer Permit. The licensed location shall be specified on the Atlantic Ocean Flounder Dealer Permit and only one location per permit shall be allowed.~~

~~(B) It is unlawful for a fish dealer to possess, buy, sell, or offer for sale more than 100 pounds of flounder from a single transaction from the Atlantic Ocean without first obtaining an Atlantic Ocean Flounder Dealer Permit.~~

~~(5) Black Sea Bass North of Cape Hatteras Dealer Permit: It is unlawful for a fish dealer to purchase or possess more than 100 pounds of black sea bass taken from the Atlantic Ocean north of Cape Hatteras (35° 15.0321' N) per day per commercial fishing operation during the open season unless the dealer has a Black Sea Bass North of Cape Hatteras Dealer Permit.~~

~~(6) Spiny Dogfish Dealer Permit: It is unlawful for a fish dealer to purchase or possess more than 100 pounds of spiny dogfish per day per commercial fishing operation unless the dealer has a Spiny Dogfish Dealer Permit.~~

(a) Aquaculture Operation Permit and Aquaculture Collection Permit:

(1) It is unlawful to conduct aquaculture operations utilizing marine and estuarine resources without first securing an Aquaculture Operation Permit from the Fisheries Director.

(2) It is unlawful:

(A) to take marine and estuarine resources from Coastal Fishing Waters for aquaculture purposes without first obtaining an Aquaculture Collection Permit from the Fisheries Director;

(B) to sell, or use for any purpose not related to North Carolina aquaculture, marine and estuarine resources taken under an Aquaculture Collection Permit; or

(C) to fail to submit to the Fisheries Director an annual report due on December 1 of each year on the form provided by the Division of Marine Fisheries the amount and disposition of marine and estuarine resources collected under authority of an Aquaculture Collection Permit.

(3) Lawfully permitted shellfish relaying activities authorized by Rules 03K .0103 and .0104 of this Chapter are exempt from requirements to have an Aquaculture Operation Permit or Aquaculture Collection Permit issued by the Fisheries Director.

(4) Aquaculture Operation Permits and Aquaculture Collection Permits shall be issued or renewed on a calendar year basis.

(5) It is unlawful to fail to provide the Division with a listing of all designees acting under an Aquaculture Collection Permit at the time of application.

(b) Atlantic Ocean Striped Bass Commercial Gear Permit:

(1) It is unlawful to take striped bass from the Atlantic Ocean in a commercial fishing operation without first obtaining an Atlantic Ocean Striped Bass Commercial Gear Permit.

(2) It is unlawful to obtain more than one Atlantic Ocean Striped Bass Commercial Gear Permit during a license year, regardless of the number of Standard Commercial Fishing licenses, Retired Standard Commercial Fishing licenses, or assignments.

(c) Blue Crab Shedding Permit: It is unlawful to possess more than 50 blue crabs in a shedding operation without first obtaining a Blue Crab Shedding Permit from the Division of Marine Fisheries.

(d) Coastal Recreational Fishing License Exemption Permit:

(1) It is unlawful for the responsible party seeking exemption from recreational fishing license requirements for eligible individuals to conduct an organized fishing event held in Joint or Coastal Fishing Waters without first obtaining a Coastal Recreational Fishing License Exemption Permit.

(2) The Coastal Recreational Fishing License Exemption Permit shall only be issued for recreational fishing activity conducted solely for the participation and benefit of one of the following groups of eligible individuals:

(A) individuals with physical or mental limitations;

(B) members of the United States Armed Forces and their dependents, upon presentation of a valid military identification card;

(C) individuals receiving instruction on recreational fishing techniques and conservation practices from employees of state or federal marine or estuarine resource management agencies, or instructors affiliated with educational institutions; and

(D) disadvantaged youths as set forth in U.S. Code 42 § 12511.

For purposes of this Paragraph, educational institutions include high schools and other secondary educational institutions.

(3) The Coastal Recreational Fishing License Exemption Permit is valid for the date, time, and physical location of the organized fishing event for which the exemption is granted and the duration of the permit shall not exceed one year from the date of issuance.

(4) The Coastal Recreational Fishing License Exemption Permit shall only be issued when all of the following, in addition to the information required in Rule .0501 of this Section, is submitted to the Fisheries Director, in writing, at least 30 days prior to the event:

(A) the name, date, time, and physical location of the event;

(B) documentation that substantiates local, state, or federal involvement in the organized fishing event, if applicable;

(C) the cost or requirements, if any, for an individual to participate in the event; and

(D) an estimate of the number of participants.

(e) Dealer permits for monitoring fisheries under a quota or allocation:

(1) During the commercial season opened by proclamation or rule for the fishery for which a dealer permit for monitoring fisheries under a quota or allocation is issued, it is unlawful for a fish dealer issued such permit to fail to:

(A) fax or send via electronic mail by noon daily, on forms provided by the Division of Marine Fisheries, the previous day's landings for the permitted fishery to the Division; contact information for the Division is provided on the forms; landings for Fridays or Saturdays shall be submitted on the following Monday; if the dealer is unable to fax or electronically mail the required information, the permittee shall call in the previous day's landings to the Division;

(B) submit the required form set forth in Part (e)(1)(A) of this Rule to the Division upon request or no later than five days after the close of the season for the fishery permitted;

(C) maintain faxes and other related documentation in accordance with Rule 03I .0114 of this Chapter;

(D) contact the Division daily regardless of whether or not a transaction for the fishery for which a dealer is permitted occurred; and

(E) record the permanent dealer identification number on the bill of lading or receipt for each transaction or shipment from the permitted fishery.

(2) Atlantic Ocean Flounder Dealer Permit:

(A) It is unlawful for a fish dealer to allow vessels holding a valid License to Land Flounder from the Atlantic Ocean to land more than 100 pounds of flounder from a single transaction at their licensed location during the open season without first obtaining an Atlantic Ocean Flounder Dealer Permit. The licensed location shall be specified on the Atlantic Ocean Flounder Dealer Permit and only one location per permit shall be allowed.

(B) It is unlawful for a fish dealer to possess, buy, sell, or offer for sale more than 100 pounds of flounder from a single transaction from the Atlantic Ocean without first obtaining an Atlantic Ocean Flounder Dealer Permit.

(3) Black Sea Bass North of Cape Hatteras Dealer Permit: It is unlawful for a fish dealer to purchase or possess more than 100 pounds of black sea bass taken from the Atlantic Ocean north of Cape Hatteras (35° 15.0321' N) per day per commercial fishing operation during the open season unless the dealer has a Black Sea Bass North of Cape Hatteras Dealer Permit.

(4) Spiny Dogfish Dealer Permit: It is unlawful for a fish dealer to purchase or possess more than 100 pounds of spiny dogfish per day per commercial fishing operation unless the dealer has a Spiny Dogfish Dealer Permit.

(5) Striped Bass Dealer Permit:

(A) It is unlawful for a fish dealer to possess, buy, sell, or offer for sale striped bass taken from the following areas without first obtaining a Striped Bass Dealer Permit validated for the applicable harvest area:

(i) Atlantic Ocean;

(ii) Albemarle Sound Management Area as designated in Rule 03R .0201 of this Chapter; or

(iii) the Joint and Coastal Fishing Waters of the Central/Southern Management Area as designated in Rule 03R .0201 of this Chapter.

(B) No permittee shall possess, buy, sell, or offer for sale striped bass taken from the harvest areas opened by proclamation without having a valid Division of Marine Fisheries-issued tag for the applicable area affixed through the mouth and gill cover or, in the case of striped bass imported from other states, a similar tag that is issued for striped bass in the state of origin. Division striped bass tags shall not be bought, sold, offered for sale, or transferred. Tags shall be obtained at the Division offices. The Division shall specify the quantity of tags to be issued based on historical striped bass landings. It is unlawful for the permittee to fail to surrender unused tags to the Division upon request.

(f) Horseshoe Crab Biomedical Use Permit:

(1) It is unlawful to use horseshoe crabs for biomedical purposes without first obtaining a permit.

(2) It is unlawful for persons who have been issued a Horseshoe Crab Biomedical Use Permit to fail to submit an annual report on the use of horseshoe crabs to the Division of Marine Fisheries due on February 1 of each year. Such reports shall be filed on forms provided by the Division and shall include a monthly account of the number of crabs harvested, statement of percent mortality up to the point of release, harvest method, number or percent of males and females, and disposition of bled crabs prior to release.

(3) It is unlawful for persons who have been issued a Horseshoe Crab Biomedical Use Permit to fail to comply with the Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan for Horseshoe Crab. The Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan for Horseshoe Crab is incorporated by reference including subsequent amendments and editions. Copies of this plan are available via the Internet from the Atlantic States Marine Fisheries Commission at http://www.asmfc.org/fisheries-management/program-overview and at the Division of Marine Fisheries, 3441 Arendell Street, P.O. Box 769, Morehead City, NC 28557, at no cost.

(g) Permit for Weekend Trawling for Live Shrimp:

(1) It is unlawful to take shrimp with trawls from 9:00 p.m. on Friday through 12:00 p.m. (noon) on Saturday without first obtaining a Permit for Weekend Trawling for Live Shrimp.

(2) It is unlawful for a holder of a Permit for Weekend Trawling for Live Shrimp to use trawls from 12:01 p.m. on Saturday through 4:59 p.m. on Sunday.

(3) It is unlawful for a permit holder during the timeframe specified in Subparagraph (k)(1) of this Rule to:

(A) use trawl nets to take live shrimp except from areas open to the harvest of shrimp with trawls;

(B) take shrimp with trawls that have a combined headrope length of greater than 40 feet in Internal Coastal Waters;

(C) possess more than one gallon of dead shrimp (heads on) per trip;

(D) fail to have a functioning live bait tank or a combination of multiple functioning live bait tanks with aerator(s) and/or circulating water, with a minimum combined tank capacity of 50 gallons; or

(E) fail to call the Division of Marine Fisheries Communications Center at 800-682-2632 or 252-726-7021 prior to each weekend use of the permit, specifying activities and location.

~~(d) Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean:~~

~~(1) It is unlawful to trawl for shrimp in the Atlantic Ocean without Turtle Excluder Devices installed in trawls within one nautical mile of the shore from Browns Inlet (34° 35.7000' N latitude) to Rich's Inlet (34° 17.6000' N latitude) without a valid Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean when allowed by proclamation as set forth in 15A NCAC 03I .0107 from April 1 through November 30.~~

~~(2) It is unlawful to tow a shrimp trawl net for more than 55 minutes from April 1 through October 31 and 75 minutes from November 1 through November 30 in the area described in Subparagraph (d)(1) of this Rule when working under this permit. Tow time begins when the doors enter the water and ends when the doors exit the water.~~

~~(3) It is unlawful to fail to empty the contents of each net at the end of each tow.~~

~~(4) It is unlawful to refuse to take observers upon request by the Division of Marine Fisheries or the National Oceanic and Atmospheric Administration Fisheries.~~

~~(5) It is unlawful to fail to report any sea turtle captured. Reports shall be made within 24 hours of the capture to the Marine Patrol Communications Center by phone. All turtles taken incidental to trawling shall be handled and resuscitated in accordance with requirements specified in 50 Code of Federal Regulations (CFR) 223.206. 50 CFR 223.206 is hereby incorporated by reference, including subsequent amendments and editions. A copy of the reference materials can be found at http://www.ecfr.gov/cgi-bin/text-idx?SID=9088932317c242b91d6a87a47b6bda54&mc=true&tpl=/ecfrbrowse/Title50/50tab_02.tpl, free of charge.~~

~~(e)~~(h) Pound Net Set Permit: The holder of a Pound Net Set Permit shall follow the Pound Net Set Permit conditions as set forth in Rule ~~15A NCAC~~ 03J .0505 ~~sets forth the specific conditions for pound net set permits.~~of this Chapter.

~~(f) Aquaculture Operation Permit and Aquaculture Collection Permit:~~

~~(1) It is unlawful to conduct aquaculture operations utilizing marine and estuarine resources without first securing an Aquaculture Operation Permit from the Fisheries Director.~~

~~(2) It is unlawful:~~

~~(A) to take marine and estuarine resources from Coastal Fishing Waters for aquaculture purposes without first obtaining an Aquaculture Collection Permit from the Fisheries Director;~~

~~(B) to sell, or use for any purpose not related to North Carolina aquaculture, marine and estuarine resources taken under an Aquaculture Collection Permit; and~~

~~(C) to fail to submit to the Fisheries Director an annual report due on December 1 of each year on the form provided by the Division the amount and disposition of marine and estuarine resources collected under authority of an Aquaculture Collection Permit.~~

~~(3) Lawfully permitted shellfish relaying activities authorized by 15A NCAC 03K .0103 and .0104 are exempt from requirements to have an Aquaculture Operation Permit or Aquaculture Collection Permit issued by the Fisheries Director.~~

~~(4) Aquaculture Operation Permits and Aquaculture Collection Permits shall be issued or renewed on a calendar year basis.~~

~~(5) It is unlawful to fail to provide the Division of Marine Fisheries with a listing of all designees acting under an Aquaculture Collection Permit at the time of application.~~

~~(g)~~(i) Scientific or Educational Activity Permit:

(1) It is unlawful for institutions or agencies seeking exemptions from license, rule, proclamation, or statutory requirements to collect, hold, culture, or exhibit for scientific or educational purposes any marine or estuarine species without first obtaining a Scientific or Educational Activity Permit.

(2) The Scientific or Educational Activity Permit shall only be issued for collection methods and possession allowances approved by the Division of Marine Fisheries.

(3) The Scientific or Educational Activity Permit shall only be issued for approved activities conducted by or under the direction of Scientific or Educational institutions as defined in Rule ~~15A NCAC 03I .0101.~~03I .0101 of this Chapter.

(4) It is unlawful for the responsible party issued a Scientific or Educational Activity Permit to fail to submit an annual report on collections and, if authorized, sales to the Division ~~of Marine Fisheries~~ due on December 1 of each year unless otherwise specified on the permit.

The reports shall be filed on forms provided by the Division. Scientific or Educational Activity permits shall be issued on a calendar year basis.

(5) It is unlawful to sell marine or estuarine species taken under a Scientific or Educational Activity Permit without:
  (A) the required license for such sale;
  (B) an authorization stated on the permit for such sale; and
  (C) providing the information required in Rule ~~15A NCAC~~ 03I .0114 of this Chapter if the sale is to a licensed fish dealer.

(6) It is unlawful to fail to provide the Division ~~of Marine Fisheries~~ a listing of all designees acting under a Scientific or Educational Activity Permit at the time of application.

(7) The permittee or designees utilizing the permit shall call the Division of Marine Fisheries Communications Center at 800-682-2632 or 252-726-7021 not later than 24 hours prior to use of the permit, specifying activities and location.

~~(h)~~(j) Under Dock Oyster Culture Permit:

(1) It is unlawful to cultivate oysters in containers under docks for personal consumption without first obtaining an Under Dock Oyster Culture Permit.

(2) An Under Dock Oyster Culture Permit shall be issued only in accordance with provisions set forth in G.S. 113-210(c).

(3) The applicant shall complete and submit an examination, with a minimum of 70 percent correct answers, based on an educational package provided by the Division of Marine Fisheries pursuant to G.S. 113-210(j). The examination demonstrates the applicant's knowledge of:
  (A) the application process;
  (B) permit criteria;
  (C) basic oyster biology and culture techniques;
  (D) shellfish harvest area closures due to pollution;
  (E) safe handling practices;
  (F) permit conditions; and
  (G) permit revocation criteria.

(4) Action by an Under Dock Oyster Culture Permit holder to encroach on or usurp the legal rights of the public to access public trust resources in Coastal Fishing Waters shall result in permit revocation.

~~(i) Atlantic Ocean Striped Bass Commercial Gear Permit:~~

~~(1) It is unlawful to take striped bass from the Atlantic Ocean in a commercial fishing operation without first obtaining an Atlantic Ocean Striped Bass Commercial Gear Permit.~~

~~(2) It is unlawful to use a single Standard Commercial Fishing License, including assignments, to obtain more than one Atlantic Ocean Striped Bass Commercial Gear Permit during a license year.~~

~~(j) Coastal Recreational Fishing License Exemption Permit:~~

~~(1) It is unlawful for the responsible party seeking exemption from recreational fishing license requirements for eligible individuals to conduct an organized fishing event held in Joint or Coastal Fishing Waters without first obtaining a Coastal Recreational Fishing License Exemption Permit.~~

~~(2) The Coastal Recreational Fishing License Exemption Permit shall only be issued for recreational fishing activity conducted solely for the participation and benefit of one of the following groups of eligible individuals:~~
  ~~(A) individuals with physical or mental limitations;~~
  ~~(B) members of the United States Armed Forces and their dependents, upon presentation of a valid military identification card;~~
  ~~(C) individuals receiving instruction on recreational fishing techniques and conservation practices from employees of state or federal marine or estuarine resource management agencies, or instructors affiliated with educational institutions; and~~
  ~~(D) disadvantaged youths as set forth in U.S. Code 42 § 12511.~~

~~For purposes of this Paragraph, educational institutions include high schools and other secondary educational institutions.~~

~~(3) The Coastal Recreational Fishing License Exemption Permit is valid for the date, time, and physical location of the organized fishing event for which the exemption is granted and the duration of the permit shall not exceed one year from the date of issuance.~~

~~(4) The Coastal Recreational Fishing License Exemption Permit shall only be issued when all of the following, in addition to the information required in 15A NCAC 03O .0501, is submitted to the Fisheries Director, in writing, at least 30 days prior to the event:~~

~~(A) the name, date, time, and physical location of the event;~~

~~(B) documentation that substantiates local, state, or federal involvement in the organized fishing event, if applicable;~~

~~(C) the cost or requirements, if any, for an individual to participate in the event; and~~

~~(D) an estimate of the number of participants.~~

~~(k) Permit for Weekend Trawling for Live Shrimp:~~

~~(1) It is unlawful to take shrimp with trawls from 9:00 p.m. on Friday through 12:00 p.m. (noon) on Saturday without first obtaining a Permit for Weekend Trawling for Live Shrimp.~~

~~(2) It is unlawful for a holder of a Permit for Weekend Trawling for Live Shrimp to use trawls from 12:01 p.m. on Saturday through 4:59 p.m. on Sunday.~~

~~(3) It is unlawful for a permit holder during the timeframe specified in Subparagraph (k)(1) of this Rule to:~~

~~(A) use trawl nets to take live shrimp except from areas open to the harvest of shrimp with trawls;~~

~~(B) take shrimp with trawls that have a combined headrope length of greater than 40 feet in Internal Coastal Waters;~~

~~(C) possess more than one gallon of dead shrimp (heads on) per trip;~~

~~(D) fail to have a functioning live bait tank or a combination of multiple functioning live bait tanks with aerator(s) and/or circulating water, with a minimum combined tank capacity of 50 gallons; and~~

~~(E) fail to call the Division of Marine Fisheries Communications Center at 800-682-2632 or 252-726-7021 prior to each weekend use of the permit, specifying activities and location.~~

Authority G.S. 113-134; 113-169.1; 113-169.2; 113-169.3; 113-182; 113-210; 143B-289.52

15A NCAC 03R .0112 ATTENDED GILL NET AREAS

(a) The attended gill net areas referenced in 15A NCAC 03J .0103(g) are delineated in the following areas:

(1) Pamlico River, west of a line beginning at a point 35° 27.5768' N - 76° 54.3612' W on Ragged Point; running southwesterly to a point 35° 26.9176' N - 76° 55.5253' W on Mauls Point;

(2) ~~Within~~ within 200 yards of any shoreline in Pamlico River and its tributaries east of a line beginning at a point 35° 27.5768' N - 76° 54.3612' W on Ragged Point; running southwesterly to a point 35° 26.9176' N - 76° 55.5253' W on Mauls Point; and west of a line beginning at a point 35° 22.3622' N - 76° 28.2032' W on Roos Point; running southerly to a point at 35° 18.5906' N - 76° 28.9530' W on Pamlico Point;

(3) Pungo River, east of the northern portion of the Pantego Creek breakwater and a line beginning at a point 35° 31.7198' N - 76° 36.9195' W on the northern side of the breakwater near Tooleys Point; running southeasterly to a point 35° 30.5312' N - 76° 35.1594' W on Durants Point;

(4) ~~Within~~ within 200 yards of any shoreline in Pungo River and its tributaries west of the northern portion of the Pantego Creek breakwater and a line beginning at a point 35° 31.7198' N - 76° 36.9195' W on the northern side of the breakwater near Tooleys Point; running southeasterly to a point 35° 30.5312' N - 76° 35.1594' W on Durants Point; and west of a line beginning at a point 35° 22.3622' N - 76° 28.2032' W on Roos Point; running southerly to a point at 35° 18.5906' N - 76° 28.9530' W on Pamlico Point;

(5) Neuse River and its tributaries northwest of the Highway 17 highrise bridge;

(6) Trent River and its tributaries; and

(7) ~~Within~~ within 200 yards of any shoreline in Neuse River and its tributaries east of the Highway 17 highrise bridge and south and west of a line beginning on Maw Point at a point 35° 09.0407' N - 76° 32.2348' W; running southeasterly near the Maw Point Shoal Marker "2" to a point 35° 08.1250' N - 76° 30.8532' W; running southeasterly near the Neuse River Entrance Marker "NR" to a point 35° 06.6212' N - 76° 28.5383' W; running southerly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River. In Core and Clubfoot creeks, the Highway 101 Bridge constitutes the attendance boundary.

(b) The attended gill net areas referenced in 15A NCAC 03J .0103(h) are delineated in the following Internal Coastal Waters and Joint Fishing Waters of the state south of a line beginning on Roanoke Marshes Point at a point 35° 48.3693' N - 75° 43.7232' W; running southeasterly to a point 35° 44.1710' N - 75° 31.0520' W on Eagles Nest Bay to the South Carolina State line:

(1) ~~All~~ all primary nursery areas described in 15A NCAC 03R .0103, all permanent secondary nursery areas described in 15A NCAC 03R .0104, and no-trawl areas described in 15A NCAC 03R .0106(2), (4), (5), (8), (10), (11), and (12);

(2) ~~In~~ in the area along the Outer Banks, beginning at a point 35° 44.1710' N - 75° 31.0520' W on Eagles Nest Bay; running northwesterly to a point 35° 45.1833' N - 75° 34.1000' W west of Pea Island; running southerly to a point 35° 40.0000' N - 75° 32.8666' W west of Beach Slough; running southeasterly and passing near Beacon "2" in Chicamicomico Channel to a point 35° 35.0000' N - 75° 29.8833' W west of the Rodanthe Pier; running southwesterly to a point 35° 28.4500' N - 75° 31.3500' W on Gull Island; running southerly to a point 35° 22.3000' N - 75° 33.2000' W near Beacon "2" in Avon Channel ; running southwesterly to a point 35° 19.0333' N - 75° 36.3166' W near Beacon "2" in Cape Channel; running southwesterly to a point 35° 15.5000' N - 75° 43.4000' W near Beacon "36" in Rollinson Channel; running southeasterly to a point 35° 14.9386' N - 75° 42.9968' W near Beacon "35" in Rollinson Channel; running southwesterly to a point 35° 14.0377' N - 75° 45.9644' W near a "Danger" Beacon northwest of Austin Reef; running southwesterly to a point 35° 11.4833' N - 75° 51.0833' W on Legged Lump; running southeasterly to a point 35° 10.9666' N - 75° 49.7166' W south of Legged Lump; running southwesterly to a point 35° 09.3000' N - 75° 54.8166' W near the west end of Clarks Reef; running westerly to a point 35° 08.4333' N - 76° 02.5000' W near Nine Foot Shoal Channel; running southerly to a point 35° 06.4000' N - 76° 04.3333' W near North Rock; running southwesterly to a point 35° 01.5833' N - 76° 11.4500' W near Beacon "HL"; running southerly to a point 35° 00.2666' N - 76° 12.2000' W; running southerly to a point 34° 59.4664' N - 76° 12.4859' W on Wainwright Island; running easterly to a point 34° 58.7853' N - 76° 09.8922' W on Core Banks; running northerly along the shoreline and across the inlets following the COLREGS Demarcation Line to the point of beginning;

(3) ~~In~~ in Core and Back sounds, beginning at a point 34° 58.7853' N - 76° 09.8922' W on Core Banks; running northwesterly to a point 34° 59.4664' N - 76° 12.4859' W on Wainwright Island; running southerly to a point 34° 58.8000' N - 76° 12.5166' W; running southeasterly to a point 34° 58.1833' N - 76° 12.3000' W; running southwesterly to a point 34° 56.4833' N - 76° 13.2833' W; running westerly to a point 34° 56.5500' N - 76° 13.6166' W; running southwesterly to a point 34° 53.5500' N - 76° 16.4166' W; running northwesterly to a point 34° 53.9166' N - 76° 17.1166' W; running southerly to a point 34° 53.4166' N - 76° 17.3500' W; running southwesterly to a point 34° 51.0617' N - 76° 21.0449' W; running southwesterly to a point 34° 48.3137' N - 76° 24.3717' W; running southwesterly to a point 34° 46.3739' N - 76° 26.1526' W; running southwesterly to a point 34° 44.5795' N - 76° 27.5136' W; running southwesterly to a point 34° 43.4895' N - 76° 28.9411' W near Beacon "37A"; running southwesterly to a point 34° 40.4500' N - 76° 30.6833' W; running westerly to a point 34° 40.7061' N - 76° 31.5893' W near Beacon "35" in Back Sound; running westerly to a point 34° 41.3178' N -76° 33.8092' W near Buoy "3"; running southwesterly to a point 34° 39.6601' N - 76° 34.4078' W on Shackleford Banks; running easterly and northeasterly along the shoreline and across the inlets following the COLREGS Demarcation lines to the point of beginning;

(4) ~~Within~~ within 200 yards of any shoreline in the area upstream of the 76° 28.0000' W longitude line beginning at a point 35° 22.3752' N - 76° 28.0000' W near Roos Point in Pamlico River; running southeasterly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River; and

(5) ~~Within~~ within 50 yards of any shoreline east of the 76° 28.0000' W longitude line beginning at a point 35° 22.3752' N - 76° 28.0000' W near Roos Point in Pamlico River; running southeasterly to a point 35° 04.4833' N - 76° 28.0000' W near Point of Marsh in Neuse River, except from October 1 through November 30, south and east of Highway 12 in Carteret County and south of a line from a point 34° 59.7942' N - 76° 14.6514' W on Camp Point; running easterly to a point at 34° 58.7853' N - 76° 09.8922' W on Core Banks; to the South Carolina State Line.

Authority G.S. 113-134; 113-173; 113-182; ~~113-221;~~ 143B-289.52