DRAFT
North Carolina
Shrimp
Fishery Management Plan
Amendment 2

By

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EXECUTIVE SUMMARY

This section to be completed prior to final adoption of the plan.

INTRODUCTION

This is Amendment 2 to the Shrimp Fishery Management Plan (FMP). By law, each FMP must be reviewed at least once every five years (G.S. 113-182.1). The N.C. Division of Marine Fisheries (NCDMF) reviews each FMP annually and a comprehensive review is undertaken about every five years. The last comprehensive review of the plan (Amendment 1) was approved by the N.C. Marine Fisheries Commission (NCMFC) in 2015. FMPs are the ultimate product that brings all information and management considerations into one document. The NCDMF prepares FMPs for adoption by the NCMFC for all commercially and recreationally significant species or fisheries that comprise state marine or estuarine resources. The goal of these plans is to ensure long-term viability of these fisheries. All management authority for the North Carolina shrimp fishery is vested in the State of North Carolina. The NCMFC adopts rules and policies and implements management measures for the shrimp fishery in Coastal Fishing Waters in accordance with 113-182.1. Until Amendment 2 is approved for management, shrimp are managed under Amendment 1 and the May 2018 Revision to Amendment 1 of the Shrimp FMP (NCDMF 2018).

FISHERY MANAGEMENT PLAN HISTORY

Original FMP Adoption:	April 2006
Amendments:	Amendment 1 – February 2015
Revisions:	May 2018 May 2021 (tentative based on rule adoption)
Supplements:	None
Information Updates:	None
Schedule Changes:	Timeline moved forward one year to start Amendment 2 in 2019 for the comprehensive review
Next Comprehensive Review:	Five years after adoption of Amendment 2

Past versions or revisions of the Shrimp FMP (NCDMF 2006, 2015, 2018, 2021) are available on the NCDMF website at: http://portal.ncdenr.org/web/mf/fmps-under-development

MANAGEMENT UNIT

The management unit includes the three major species of shrimp: brown (*Farfantepenaeus aztecus),* pink (*F. duorarum*), and white (*Litopenaeus setiferus*) and their fisheries in all coastal fishing waters of North Carolina, which includes the Atlantic Ocean offshore to three miles.

GOAL AND OBJECTIVES

The goal of Amendment 2 to the N.C. Shrimp FMP is to manage the shrimp fishery to provide adequate resource protection, optimize long-term harvest, and minimize ecosystem impacts. The following objectives will be used to achieve this goal.

- Reduce bycatch of non-target species of finfish and crustaceans, as well as protected, threatened, and endangered species.
- Promote the restoration, enhancement, and protection of habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan (CHPP).
- Develop a strategy through the CHPP to review current nursery areas and to identify and evaluate potential areas suitable for designation.
- Use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the shrimp fishery and its ecosystem impacts (i.e., bycatch, habitat degradation).
- Promote implementation of research and education programs designed to improve stakeholder and the general public's understanding of shrimp trawl bycatch impacts on fish population dynamics.

DESCRIPTION OF THE STOCK

BIOLOGICAL PROFILE

There are three species that make up the shrimp fishery in North Carolina. They are the brown shrimp, pink shrimp, and white shrimp. Brown shrimp occur from Massachusetts to the Florida Keys and into the Gulf of Mexico to northwestern Yucatan (Larson 1989; Williams 1984). High abundances of brown shrimp occur in the Gulf of Mexico supporting a major commercial fishery along the South Atlantic coast, primarily in North and South Carolina. Pink shrimp are found from southern Chesapeake Bay to the Florida Keys, and around the coast through the Gulf of Mexico to Yucatan (Bielsa et al. 1983). The largest population of pink shrimp is off southwestern Florida in the Tortugas and Sanibel as well as in the southeastern portion of Bay of Campeche. Significant quantities of pink shrimp have historically been reported off the North Carolina coast and the northeast Florida coast; however, since the late 1990s their abundance has declined in North Carolina. White shrimp occur along the Atlantic coast from New York to Florida and throughout the Gulf of Mexico (Muncy 1984; Steele 2002).

The lifecycle of these species are similar in that adults spawn offshore and eggs are hatched into free-swimming larvae. Larvae develop through several stages into post-larvae. Once post-larval shrimp enter estuaries, growth is rapid and is dependent on salinity and water temperature. As shrimp increase in size, they migrate from the upper reaches of small creeks to deeper saltier rivers and sounds. By late summer and fall, they return to the ocean to spawn. The maximum life span of shrimp can range from 16 to 24 months and may reach a size of 7 to 11 inches, depending on species (Eldred et al. 1961; Gunter 1961; McCoy 1968, 1972; McCoy and Brown 1967; Williams 1984).

Significant weather events such as droughts, hurricanes, and changes in climate can influence the occurrence and distribution of marine organisms and habitat. While extreme weather events have always occurred, there is scientific consensus that climate change is occurring in North Carolina. Some of the expected weather related changes on the east coast resulting from climate change include increasing water temperatures, frequency of heavy rain events, severity of tropical storms, rate of sea level rise, and non-storm event nuisance flooding with more long-term effects on the estuarine system (Paerl et al. 2006; Melillo et al. 2014; Sweet et al. 2014; IPCC 2018; Kunkel et al. 2020). As the climate changes and waters warm, shrimp abundance and distribution shifts can occur. It has been predicted the ranges of hundreds of finfish and invertebrate species will shift or expand northward due to increasing temperatures caused by climate change (Morley et al. 2018).

In recent years, some monitoring programs are showing the expansion of white shrimp at the mouth of the Chesapeake Bay and off the coast of Cape Hatteras. Water temperatures have increased with milder winters and may be contributing to higher white shrimp abundance at the northern end of their range (Delancey et al. 2008; Kimbell et al. 2020; VIMS 2020). Warming winter temperatures may have the opposite effect on brown shrimp disrupting recruitment of post-larvae into the estuaries (David Whitaker, SCDNR (retired), personal communication). Post-larvae brown shrimp bury into bottom sediments as temperatures decline and then emerge as temperatures rise in late winter or early spring (Aldrich et al. 1968). If winter water temperatures do not decline enough to elicit this bottom-seeking behavior, then the post-larvae may recruit to the estuary throughout the winter, becoming exposed to periodic lethal low water temperature in the shallow tidal creeks.

Rising water temperatures associated with climate change have been linked to a rise in “black gill” infections in white shrimp which are thought to negatively impact penaeid shrimp fisheries in Georgia and South Carolina (Fowler et al. 2018; Frischer et al. 2018). Black gill is a parasitic infection caused by single-celled protozoans called ciliates that cause the shrimp’s immune system to produce an enzyme to fight the infection in a process known as melanization, giving the gills a black appearance (Johnson 1978; Burnett and Burnett 2015; Frischer et al. 2018). This process can impair respiratory function, growth, reproduction, and enhance the hosts susceptibility to environmental factors and predation (Gooding et al. 2020). Black gill has been observed in pink, brown, and white shrimp and is not harmful to humans (Johnson 1978).

Shrimp are preyed upon by numerous finfish, invertebrates, and a wide variety of coastal and wading birds (NCDMF 2015). Predation is cited as a major source of natural mortality for juvenile shrimp and decreases as they grow (Zimmerman et al. 2000; Ramirez-Rodriguez and Sanchez 2003; Baker and Minello 2010; Leo et al. 2016). Trends in natural mortality are thought to be the result of age specific predation rates, physiological requirements, and the physical environment acting on different life history stages of penaeid shrimp (Ramirez-Rodriguez and Sanchez 2003).

STOCK STATUS

Stock status is not available for all species of shrimp as they are considered an annual crop in North Carolina. Estimates of population size are not available but since shrimp are considered an annual crop and fished at near maximum levels, annual landings are probably a good indication of relative abundance. Population size is controlled by environmental conditions, and while fishing reduces the population size over the season, fishing is not believed to impact year class strength unless the spawning stock has been reduced below a minimum threshold level by environmental conditions. Annual variations in catch are presumed to be due to a combination of environmental conditions, fishing effort, and the effects of changes in the economics of the fishery. Because of high fecundity and migratory behavior, the three species are capable of rebounding from very low population sizes in one year to large populations the next, provided environmental conditions are favorable (MacArthur and Wilson 1967; McCoy and Brown 1967; McCoy 1968, 1972; Perez-Farfante 1969; Purvis and McCoy 1972; Whitaker 1981, 1983).

The division's Estuarine Trawl Survey (Program 120) is a fishery-independent multispecies monitoring program that has been ongoing since 1971 in the months of May and June. One of the key objectives of this program is to provide long-term indices of annual juvenile recruitment for multiple species. From this survey, annual trends in brown shrimp abundance measured as the number of brown shrimp per station (relative abundance) shows fluctuations from year to year. Estimates of year class strength can be inferred from the annual brown shrimp index of relative abundance and track brown shrimp landings in June and July, months where brown shrimp make up most of the landings (Figure 1). Currently, there are no juvenile indices for white and pink shrimp in North Carolina because sampling does not cover their recruitment time period. However, in recent years, higher abundances of white shrimp have been observed in the estuarine trawl survey in June and also track with peak white shrimp landings in October (Figure 2).

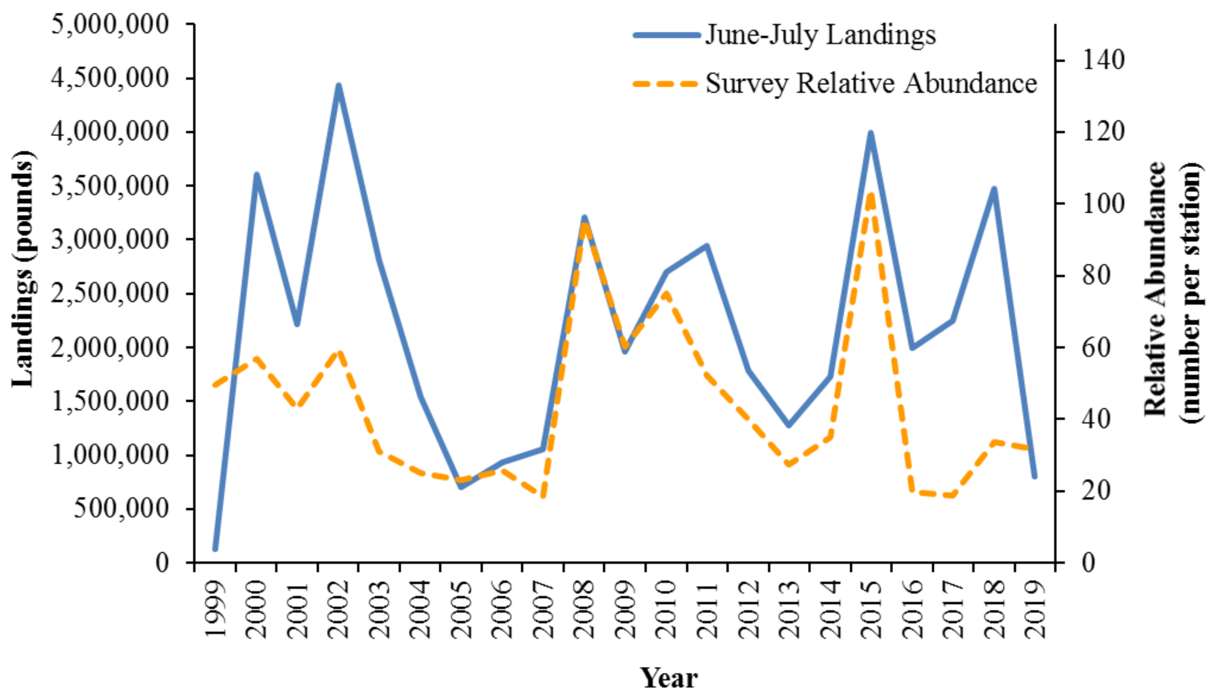

Figure 1. Comparison of brown shrimp commercial landings in the months of June and July to the brown shrimp Estuarine Trawl Survey index of relative abundance in May and June (number per station), 1999-2019.

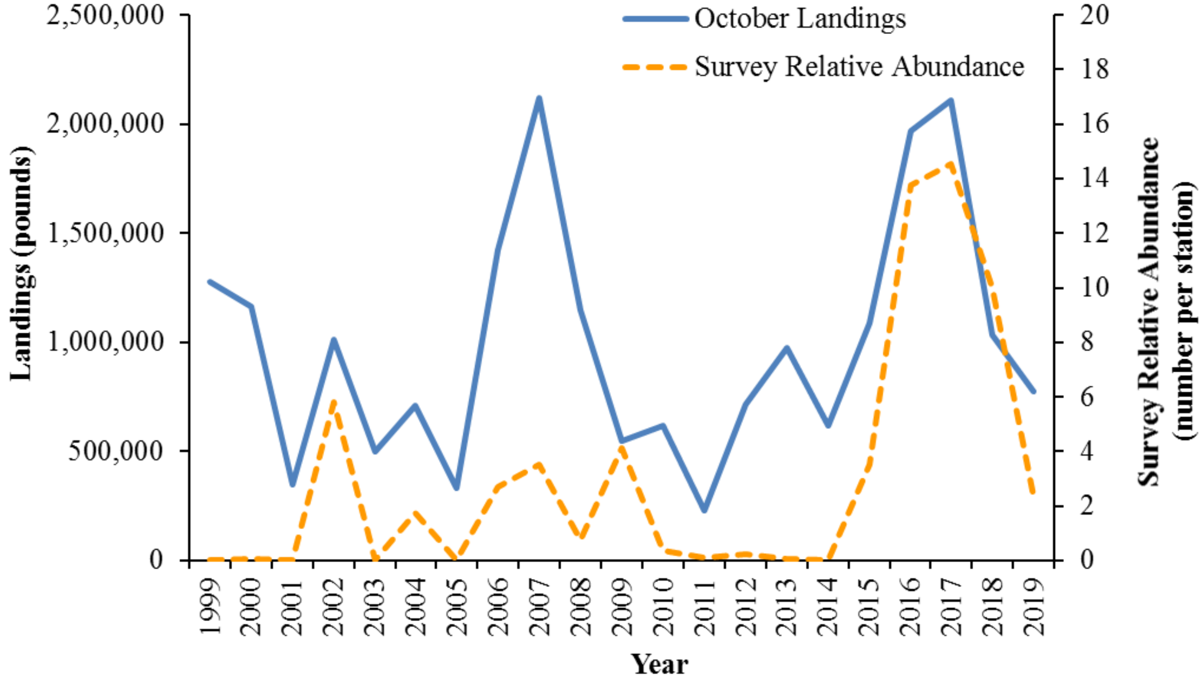

Figure 2. Comparison of white shrimp commercial landings in October to the relative abundance (number per station) of white shrimp in the Estuarine Trawl Survey in June, 1999-2019.

DESCRIPTION OF THE FISHERIES

Additional in-depth analyses and discussion of North Carolina's commercial and recreational shrimp fisheries can be found in earlier versions of the Shrimp FMP (NCDMF 2006, 2015, 2018); all documents are available on the NCDMF website at: http://portal.ncdenr.org/web/mf/fmps-under-development and the License and Statistics Annual Report (NCDMF 2020) produced by the NCDMF which can be found at: http://portal.ncdenr.org/web/mf/marine-fisheries-catch-statistics.

COMMERCIAL FISHERIES

Historical landings statistics were collected on a voluntary basis and methodology varied through time until 1994 when the NCDMF implemented a mandatory Trip Ticket Program to monitor commercial landings and fishing effort (Lupton and Phalen 1996). While commercial shrimp fishery data exists for small geographic areas and short windows of time, commercial landings and associated effort from the Trip Ticket Program is the only statewide data source with a long time series. Commercial shrimp harvest for NC's estuarine and state ocean waters requires a fisherman to hold a Standard Commercial Fishing License (SCFL) or a Retired Standard Commercial Fishing License (RSCFL). A Land or Sell License can be used to commercially harvest shrimp from ocean waters greater than three miles from shore and for a vessel that is registered in another state, as well as the SCFL and RSCFL.

A variety of methods are used to catch shrimp including otter trawls, skimmer trawls, channel nets, shrimp pounds, and cast nets. Otter trawls derived their name from the two trawl doors (otter doors/boards) that attach to the bridle that are hydro-dynamically designed to hold the wings of the net open (Figure 3; Jennings et al. 2001). As the net is pulled along the bottom, the otter boards plane in opposite directions holding the net open. Otter trawls are used for all three species in both the estuary and the ocean with two-seam trawls used for brown and pink shrimp and four-seam and tongue trawls for white shrimp, which tend to swim higher in the water column and will jump to the surface when disturbed. Skimmer trawls consists of two rigid frames attached to each side of a vessel with nets attached along the two sides of the frame (Figure 4). Metal skids keep the frames off the bottom as the nets are pushed through the water column. Unlike otter trawls, the tailbags of skimmer trawls can be checked while fishing. Skimmer trawls are primarily used for white shrimp and are capable of fishing waters as shallow as two feet.

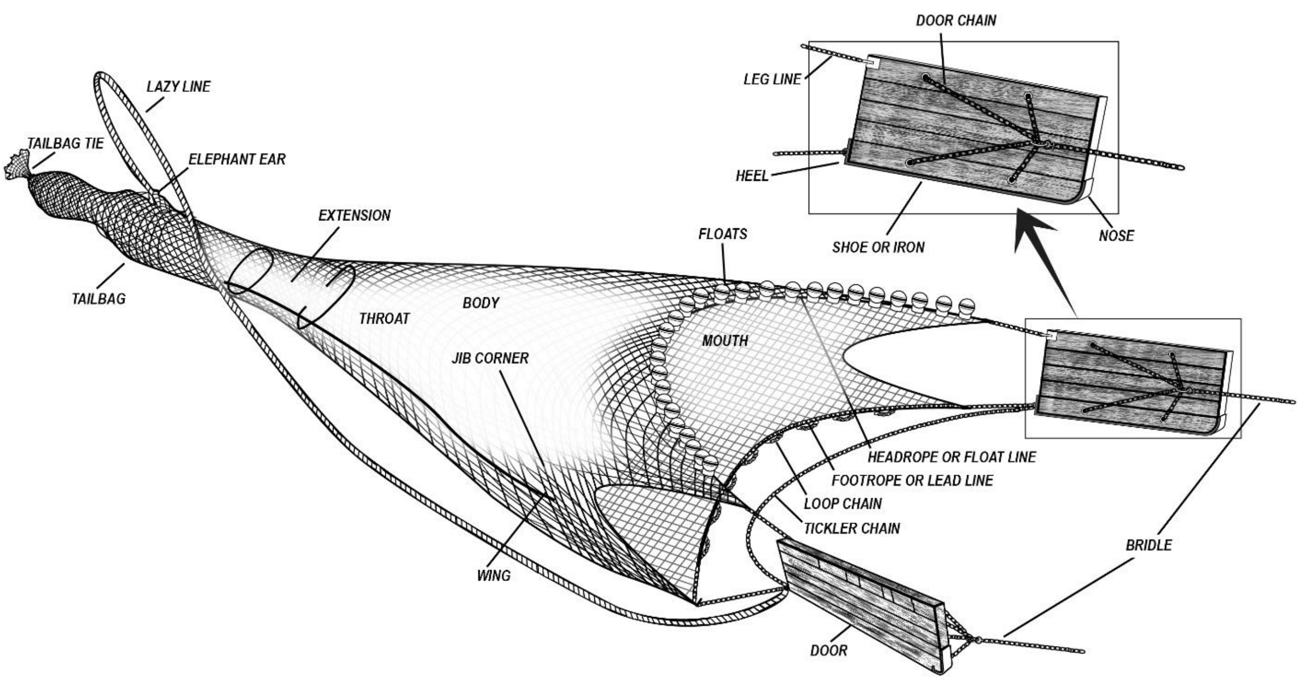

Figure 3. Schematic of otter trawl components.

Channel nets are stationary nets that use tidal currents to fish the surface and middle depths of the water column (Figure 5). The mouth of the nets is held open by upright wooden shafts attached to a buoy and anchor on one side and a small vessel on the other. Float and butterfly nets also make use of tidal currents to push shrimp into the nets and offer the advantages of less fuel consumption and less bycatch than traditional shrimp trawls. To shrimp with a “float net”, fishermen attach large floats to the doors and top lines of trawls to make the net fish up in the water column and are pulled slowly forward to harvest shrimp that are migrating to the inlets at night. Butterfly nets use this same harvest strategy but are attached to a metal frame and are held stationary in the water column to capture shrimp as the current carries them into the net. Trawls, cast nets and seines are used to harvest live shrimp for the commercial bait fishery. As of 2019, otter trawls account for most of the commercial shrimp harvest with skimmer trawls and channel nets ranking a distant second and third. From 2004 to 2019, approximately 93% of shrimp landings have been from otter trawls, 5% from skimmer trawls, and 2% from channel nets. Landings from other gears account for less than 1% of the total landings which include shrimp pots (Figure 6A), pound nets (Figure 6B), cast nets, and gill nets.

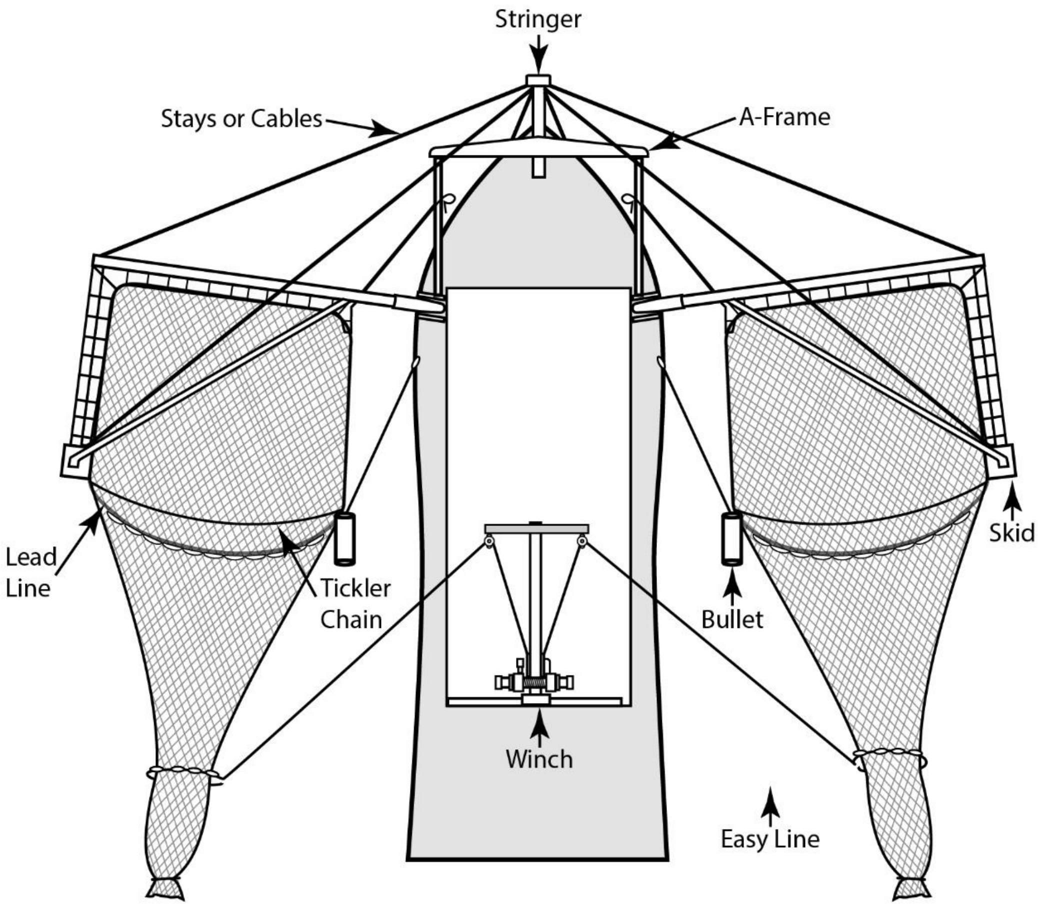

Figure 4. Schematic of skimmer trawler components.

North Carolina's shrimp fishery is unusual in the southeast U.S. because all three species are harvested and most of the effort occurs in internal waters. While South Carolina, Georgia, and Florida allow limited shrimping in internal waters, much of their fisheries are conducted in the Atlantic Ocean and white shrimp comprise most of their harvest (NCDMF 2015). Most of the vessels that operate in the NC commercial shrimp fishery are registered in NC. The number of NC registered vessels ranged from 394 in 2011 to 606 in 2004. The number of vessels registered in other states ranged from five in 2005 to 39 in 2017. In 2019, only 16 vessels registered in other states landed 4.4% of the total shrimp landings.

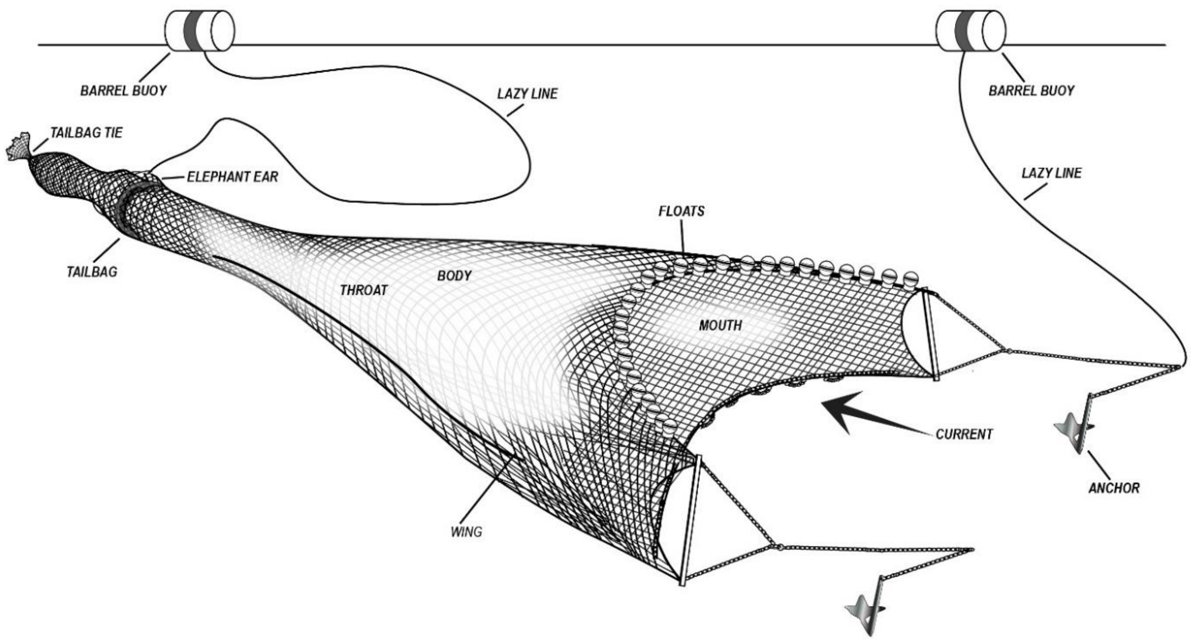

Figure 5. Schematic of channel net components.

Larger vessels are mostly used to trawl in the deeper waters in Pamlico Sound and the mouths of the Neuse, Pamlico, Pungo, and Bay rivers; and the ocean. Smaller vessels are more often used to trawl in the smaller sounds (Croatan, Roanoke, and Core sounds) and rivers (Newport, North, and White Oak rivers). Most trawling in the central portion of the state is conducted at night. Channel nets are popular around Harkers Island in the Straits and North River while skimmer trawling is very popular in Newport River and Bogue Sound. In the southern portion of the state, the fishery is mostly small boats fishing primarily the Intracoastal Waterway, New, and Cape Fear rivers and larger vessels fishing the Atlantic Ocean primarily off New River, Carolina Beach, and Brunswick County. Many of the small boats are fished by individuals who shrimp part-time or for personal consumption. Channel nets are fished extensively in the areas around New River and Topsail inlets. Skimmer trawls have become more popular around New River and Topsail Sound.

Historically, landings decline during the late fall and through the winter. However, in recent years, landings in December and January have increased substantially due to an abundance of white shrimp in near shore ocean waters north of Cape Hatteras from Oregon Inlet to the NC-VA state line. Landings of shrimp are lowest during the late winter and early spring months. Average monthly landings and dockside value are highest in the summer and early fall months from July through October.

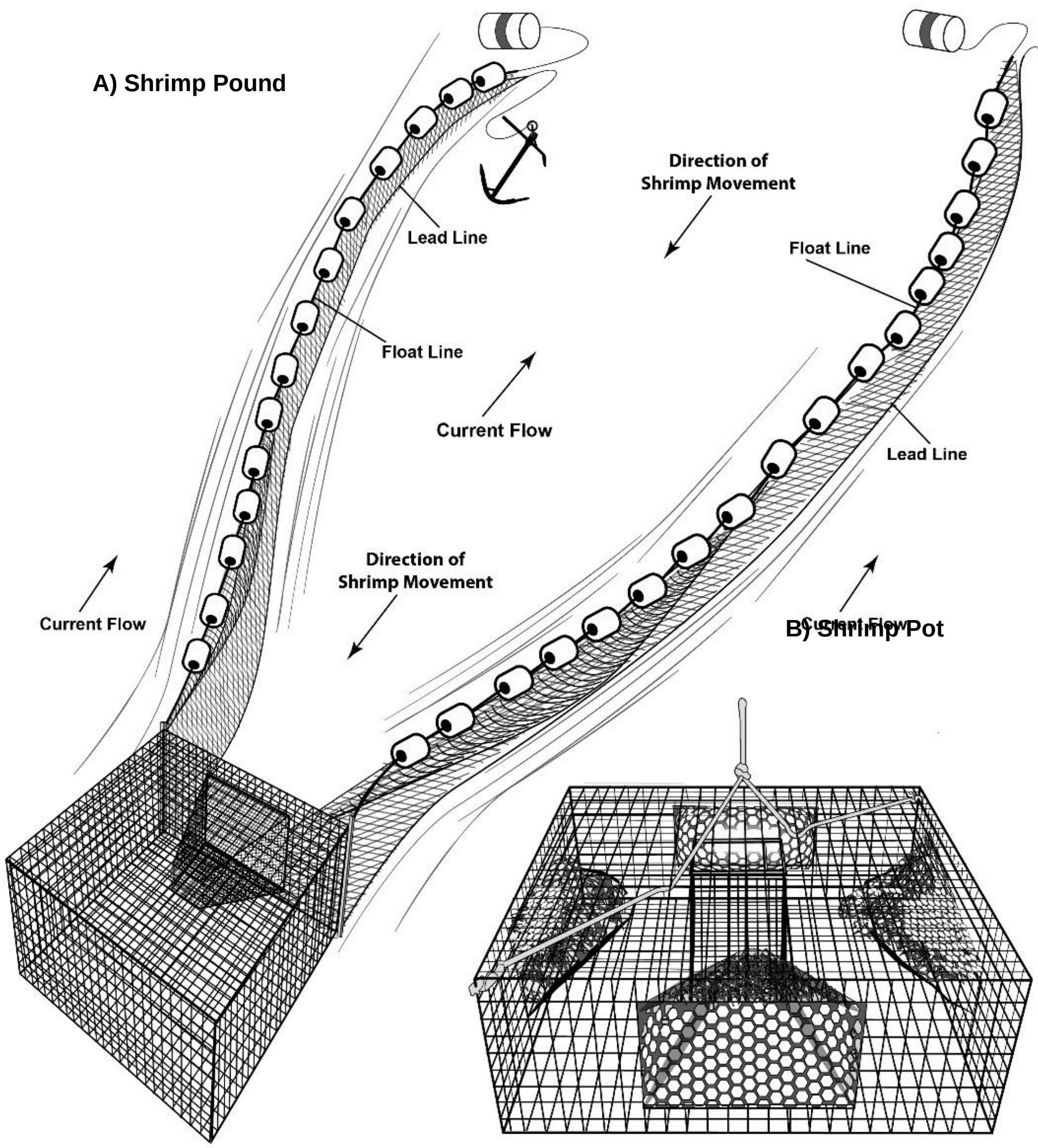

Figure 6. Schematic of shrimp pound (A) and shrimp pot (B) components.

Trends are shown for the dockside (ex-vessel) value and harvest volume presented as heads-on weight in pounds for shrimp. Total landings of all three shrimp species combined from 1994 to 2019 have averaged 7,430,164 pounds per year (Figure 7). The lowest landings during this period was 2.36 million pounds in 2005 and the highest was 13.91 million pounds in 2017. Shrimp landings have increased in recent years exceeding 9 million pounds since 2015. Annual dockside value of commercial shrimp landings averaged $15.46 million from 2004 to 2019. Annual dockside value was lowest in 2005 at $4.41 million and reached a high of over $30.32 million in 2017.

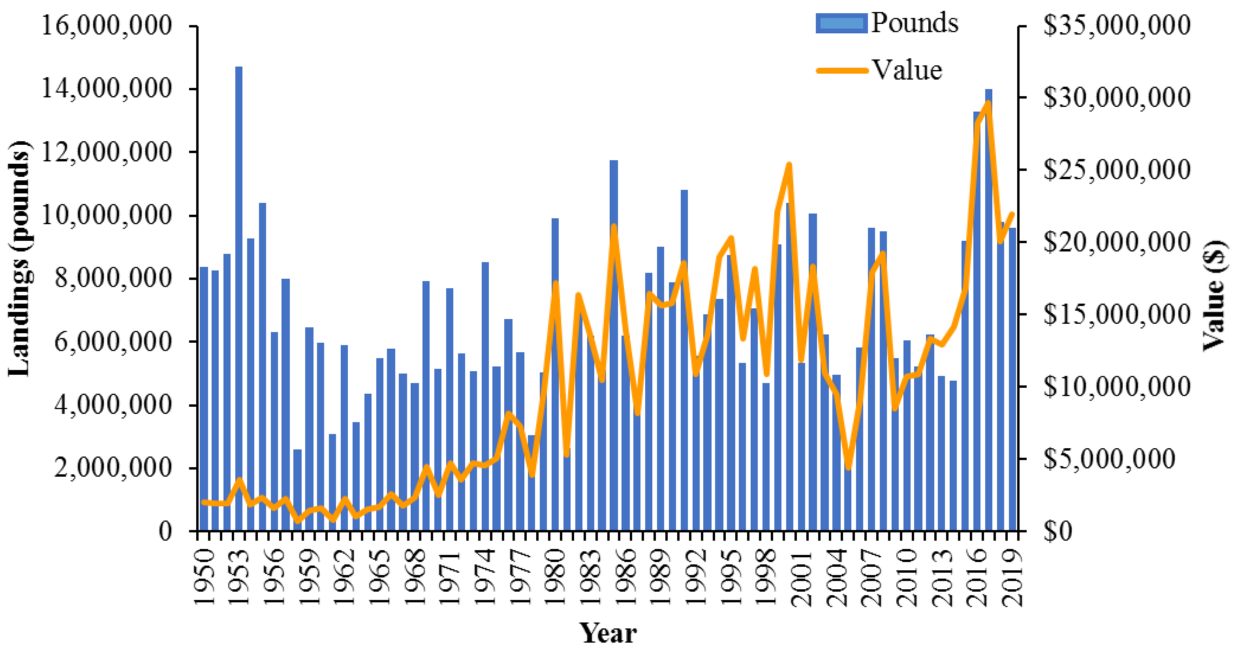

Figure 7. North Carolina annual shrimp commercial landings (pounds) and value ($), 1950-2019.

Annual shrimping effort (number of trips) has fluctuated with shrimp abundance but has gradually declined since 1994 due to a number of factors including cheaper imported shrimp prices, increasing fuel prices, and fishermen retiring (NCDMF 2015; Figure 8). The number of trips decreased 2% from 2018 to 2019 (Figure 8). Landings in 2005 were lowest on record, likely because of several reasons including; many large trawlers remained scalloping instead of shrimping because prices were high and the days at sea were extended (NCDMF 2015), Hurricanes Katrina (Aug. 29, 2005) and Rita (Sept. 4, 2005) hit the Gulf coast, negatively affecting the fishing industry, shrimp breading operations in the Gulf shut down with only one operational in September and some North Carolina shrimpers could not sell their product (NCDMF 2015). Hurricane Florence (Sept. 17, 2018) directly hit North Carolina, likely contributing to the decrease in landings in 2018.

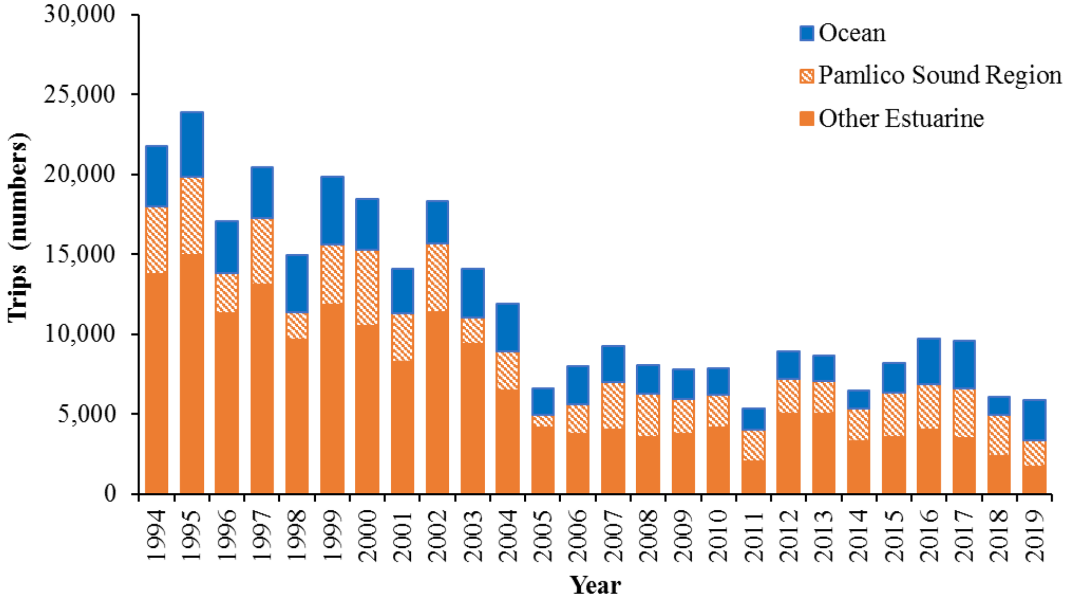

Figure 8. Annual number of commercial trips reported for all three species by area, 1994-2019. Data from the NCDMF Trip Ticket Program.

In 2018, most (82%) of the harvest occurred in estuarine waters (Pamlico Sound and estuarine other regions); however, only 36% occurred in estuarine waters in 2019 (Figure 9). Since 1994, the Pamlico Sound has accounted for roughly 56% of total commercial shrimp landings in North Carolina. Landings in the Atlantic Ocean (less than 3 miles from shore) increased 251% in 2019 and were well above the times series average.

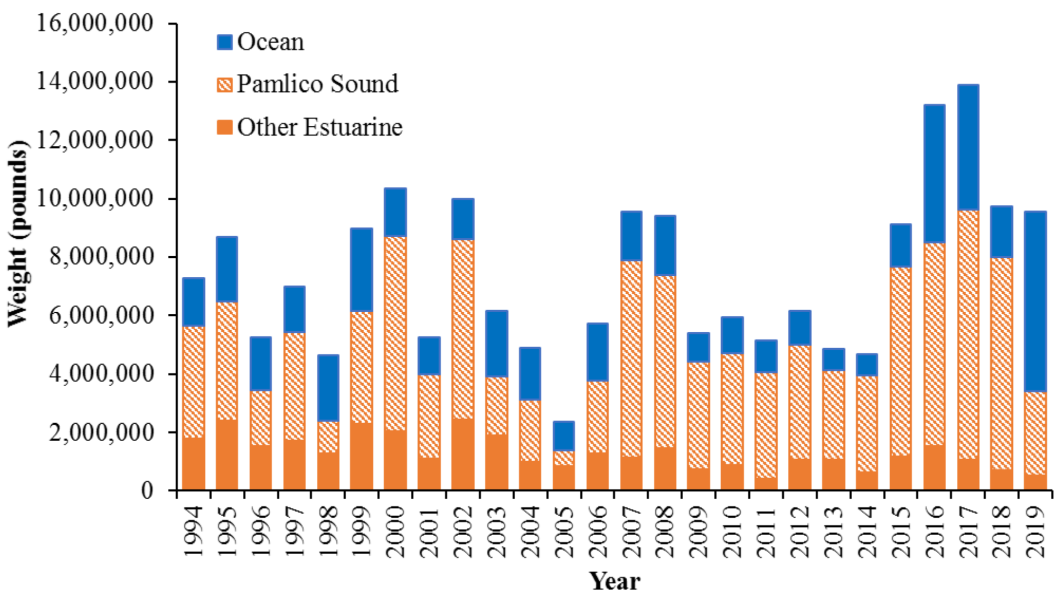

Figure 9. Annual commercial shrimp landings (pounds) by area for all three shrimp species combined in North Carolina, 1994-2019. Data from the NCDMF Trip Ticket Program.

See *Appendix 2.4: Managing Effort and Gear Modifications in the Shrimp Fishery to Reduce Bycatch* and *Appendix 2.3: Area Restrictions to Reduce Shrimp Trawl Bycatch in North Carolina* for detailed commercial landings by gear and area.

Summary of Economic Impact of Commercial Shrimp Fishing

As one of the largest and most valuable commercial fisheries in the state, shrimp is a strong economic driver for the industry, supporting year-round seafood production, in-state consumption, and national exports. From 2004 to 2019, the value of the commercial shrimp harvest constituted roughly 20% of all commercial landings, with that proportion increasing to 25 to 30% in recent years. However, this valuable fishery is relatively concentrated, with fewer than 500 participants recording shrimp harvest most years. In fact, as the total value generated from commercial shrimp harvest increased from 2004 to 2019, the number of participants has decreased slightly, demonstrating an even greater concentration over time.

In addition to catch statistics and associated dockside values, the estimated total economic impact of this industry to the state of North Carolina can be modelled using IMPLAN statistical software. This method takes the direct contribution of the fishery (ex-vessel output and employment) along with federal fisheries data to model the total economic contribution to jobs, income, output, and value-added impacts. For a detailed explanation of the methodology used to estimate the economic impacts please refer to the NCDMF's License and Statistics Section Annual Report (NCDMF 2020).

To capture this total contribution, IMPLAN estimates three types of impacts: direct, indirect, and induced. For commercial shrimp fishing, direct effects are those felt at the fishery level, indirect effects occur from business-to-business spending related to the fishery, such as transport and processing, and induced effects are the state-level impacts of household spending from incomes gained through the commercial shrimp fishery. The values in Figure 10 represent the summed totals of direct, indirect, and induced impacts. While economic impacts can only be estimated starting in 2008, these data reflect the same landings trends of increasing value over time (Figure 10). Despite slight decreases in 2018 and 2019, the commercial shrimp industry helps promote a robust seafood economy, generating nearly $100 million in state-wide sales impacts. While the number of licensed shrimp fishery participants is low, commercial shrimp harvest helps generate an estimated 1,000 to 2,000 additional jobs annually, underscoring the broader impact to the state's overall economy.

In addition to the economic influences of the global shrimp market, environmental concerns within North Carolina also act as a significant driver of this industry's value. Given the biology and life-histories of shrimp, fishing for this product requires methods that are generally deemed more environmentally destructive, such as trawling (MSC 1996; NCDEQ 2016). The environmental externalities that shrimp harvest incur can drive down demand for wild-caught shrimp, which, along with the need to price-adjust for environmental damages, can ultimately force North Carolina shrimp to sell at a prohibitively high price for many consumers. On top of this, shrimp are highly sensitive to environmental conditions, requiring additional concern for environmental protection when considering shrimp management. In all, these factors help demonstrate many of the hidden costs within the North Carolina shrimp harvest, and how that affects both the price and value of these products moving forward.

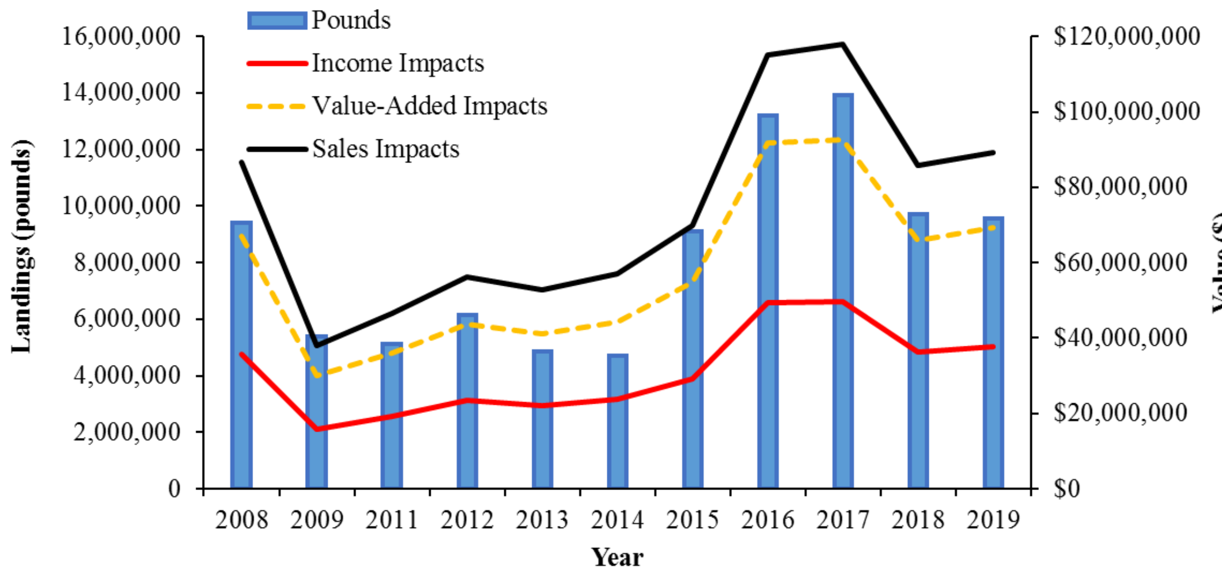

Figure 10. Economic impact estimates to the state of North Carolina from commercial shrimp harvest, 2008-2019. Estimates are generated using IMPLAN economic modelling software, data from NOAA's Fisheries Economics of the U.S. Reports, and NCDMF Trip Ticket data. Income impacts represent the total additional income generated in NC by the commercial shrimp industry (includes wages, benefits, and proprietor income). Value-added impacts represent the total value of the commercial shrimp industry's economic production to NC. Sales impacts represents the output value of the commercial shrimp industry and is the closest proxy of the industry's contribution to NC's annual gross domestic product (value added through the production of goods and services). These various impact estimates are not additive and should be considered independently. Note: expenditure data from NOAA's "Fisheries Economics of the U.S." is only available beginning in 2008.

Lastly, during the shrimp FMP advisory committee process, members discussed NCDMF's ability to accurately quantify the economic impacts of management changes and questioned what steps would be needed to conduct this analysis. While this quantification may be possible with sufficient data, the Division lacks much of the required information to produce a reliable estimate spanning biological, economic, and social data gaps. In order to evaluate the economic impacts of management changes for the shrimp fishery, the Division would need highly accurate estimates of the stock status of each species related to the shrimp fishery, projections of how these stocks would react to various management changes, and the holistic value of each of these stocks are (including commercial, recreational, and non-use values). Beyond this, detailed participant-level data would need to be collected across a range of stakeholders, while the economic value of a variety of indirect components, such as improved water quality, enhanced broodstock habitat, reduced user conflict, or changes in market behavior, would also need to be accurately quantified to incorporate into the calculation. At this time the Division has a strong understanding of how specific management changes would impact the economics of the fishery at a functional level, but a holistic economic impact quantification would require enhanced data streams from a wide set of sources that is not feasible within the timeline of the current FMP.

RECREATIONAL FISHERY

Within the division's recreational fishery monitoring programs [Marine Recreational Information Program (MRIP), Gigging Mail Survey, Cast Net and Seine Mail Survey, and the Recreational Commercial Gear License (RCGL) Survey], the MRIP and Gigging Mail Survey do not collect data with respect to shrimp. Recreational shrimp harvest data are limited to the Cast Net and Seine Mail Survey and the RCGL Survey.

Recreational fishermen harvest shrimp for personal consumption and for use as bait. A RCGL is required to recreationally harvest shrimp using a limited amount of commercial gear. Commercial gear allowed under a RCGL license that target shrimp include otter and skimmer trawls with a headrope length up to 26-feet, a 100-foot seine, one shrimp pound net, and up to five shrimp, crab, and fish pots each. Seines measuring less than 30 feet long and cast nets are exempt from this license. Shrimp harvested under a RCGL license cannot be sold and is for personal consumption only. Recreational fishermen are limited to 48 quarts of head-on (30 quarts of head-off) shrimp per person, per day or if a vessel is used, per vessel per day (RCGL maximum limit is two per vessel). Cast nets are the only gear allowed in closed shrimping areas, and recreational fisherman can harvest four quarts of head-on or two-and-a-half quarts of head-off shrimp per person, per day. For additional information on RCGL guidelines and rules, visit:
http://portal.ncdenr.org/web/mf/recreational-commercial-gear-license.

Harvest data from RCGL gears are only available from 2004 to 2008 due to no funding of the RCGL survey. The number of licensed individuals participating in the RCGL fishery has steadily decreased from 6,356 in 2001 to 1,980 in 2019 (Figure 11). This is the best indicator currently available of effort in the RCGL fishery. For additional information on licenses see the License and Statistics Annual Report or for RCGL survey analysis see the 2009 License and Statistics Annual Report (NCDMF 2009).

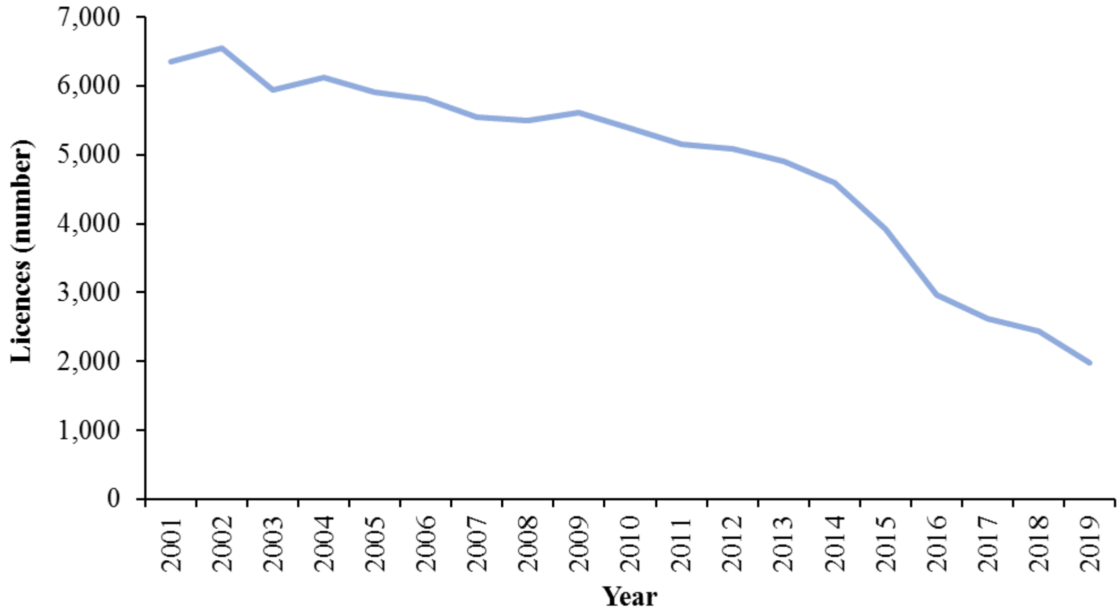

Figure 11. The number of Recreational Commercial Gear License (RCGLs) issued 2001-2019.

From 2012 to 2019, the estimated total number of shrimp caught (harvest and released) using a cast net and/or seine ranged from 90,651 in 2018 to 296,692 in 2016, with an estimated annual average of 189,022 shrimp. Total shrimp harvest ranged from 83,266 in 2019 to 237,433 in 2016 (Figure 7). The estimated average of shrimp harvested annually over this eight-year period was 161,235. The months of July/August had the greatest number of shrimp harvested, closely followed by September/October and May/June. Annual trips ranged from 95,784 in 2018 to 217,484 in 2015 (Figure 12).

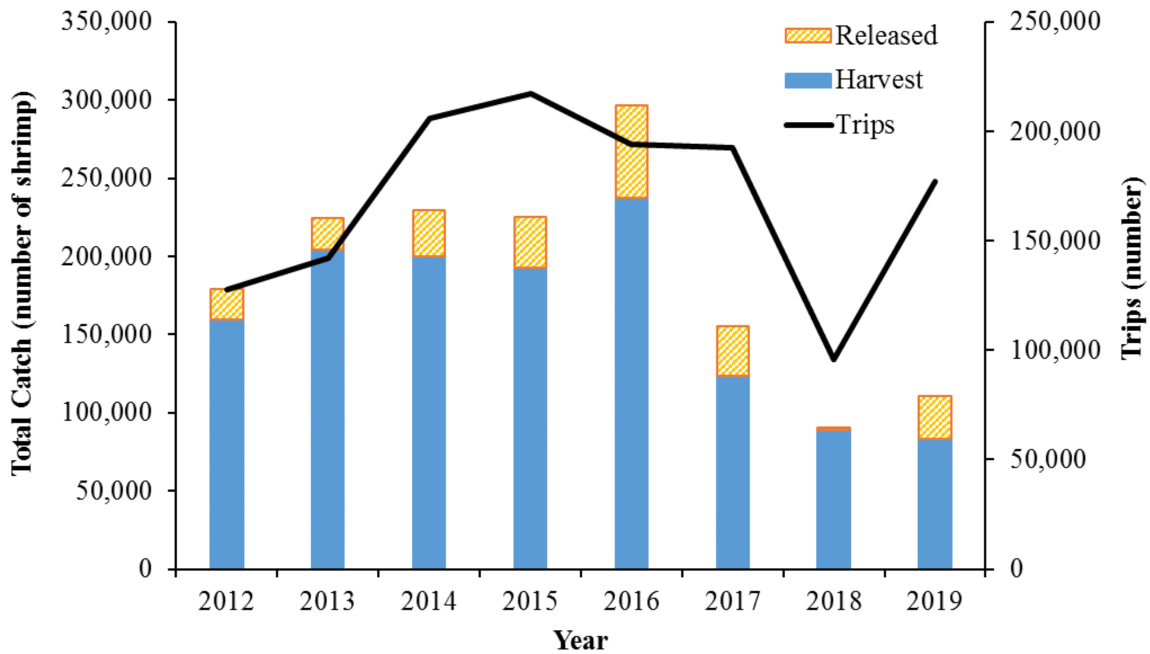

Figure 12. Annual number of shrimp harvested and trips taken from cast nets and seines for recreational purposes, 2012-2019.

Summary of Economic Impact of Recreational Shrimp Fishing

Overall, recreational effort and harvest for shrimp in North Carolina is very difficult to track and quantify. However, shrimp play a significant role in the recreational fishing industry overall in North Carolina, and it is important to note this species' role and how it affects the recreational fishing economy at-large. Specifically, shrimp serve as one of the primary bait species for recreational anglers in the state, and bait shrimp are sold in tackle shops, gas stations, big-box stores, and a variety of other locations. Depending on target species, anglers allocate a significant portion of their bait and tackle spending to shrimp each season, which contributes strongly to the sales of many tackle shops. Additionally, the need to purchase bait shrimp can also lead to spillover spending, these goods bring anglers into tackle shops and related stores, leading to additional spending. On top of this, some anglers choose to catch their own bait shrimp via cast nets and seines, which also drives gear purchases throughout the state. In short, shrimp are an important component of recreational angling, and contribute greatly to recreational bait, tackle, and gear spending, which generates significant economic impacts to the state of North Carolina.

BYCATCH

Bycatch is the portion of a catch taken incidentally to the targeted catch because of non-selectivity of the fishing gear to either species or size differences (ASMFC 1994). In North Carolina, numerous studies have been conducted to characterize bycatch in the commercial shrimp trawl fishery (Roelof 1950; Pearce et al. 1988; McKenna et al. 1993, 1996; Diamond-Tissue 1999; Johnson 2003, 2006; Logothetis and McCuiston 2004; Brown 2009, 2010, 2015, 2016; Brown et al. 2017, 2018). While many species of finfish are caught as bycatch in the shrimp trawl fishery, the bycatch of Atlantic croaker (*Micropogonias undulatus*), southern flounder (*Paralichthys lethostigma*), summer flounder (*P. dentatus*), spot (*Leiostomus xanthurus*), and weakfish (*Cynoscion regalis*) are of particular concern due to their value as economically important recreational and commercial fisheries as well as concerns about their stock status.

In 1990, NCDMF began testing the use of Bycatch Reduction Devices (BRDs) in shrimp trawls to reduce finfish bycatch. Results from this work led to North Carolina becoming the first state to mandate the use of BRDs in all shrimp trawls in 1992. The use of BRDs installed in shrimp trawls can reduce total bycatch by 30 to 70% (McHugh et al. 2016). North Carolina has continued testing and working with the industry to modify trawl gears to reduce bycatch.

Of federally protected species found in North Carolina, sea turtles, sturgeon, and the common bottlenose dolphin (*Tursiops truncatus*) are known or suspected to be incidentally taken in the shrimp fishery. Turtle Excluder Devices (TEDs) in trawls are estimated to have a 97% exclusion rate of sea turtles with minimal shrimp loss (Watson 1981; Federal Register 1987, 1992; NOAA 2020). The use of TEDs has also shown to reduce finfish bycatch (Brewer et al. 2006; Broome et al. 2011; Price and Gearhart 2011).

While bottlenose dolphins are commonly seen feeding behind shrimp trawlers in North Carolina (Fleming 2004; Johnson 2006; Brown 2009), very few takes have been observed in the shrimp trawl fishery. Bycatch of Atlantic sturgeon (*Acipenser oxyrinchus*) is thought to be the primary source of mortality and biggest threat to the species recovery (ASMFC 2017). Results from the 2017 Atlantic Sturgeon Stock Assessment Report indicate the total and dead bycatch of Atlantic sturgeon from otter trawls has declined since 2002 and the stock is showing signs of recovery (ASMFC 2017). In an evaluation of TED designs used in the Mid-Atlantic croaker flynet fishery, Atlantic sturgeon were observed escaping through TED openings (Gearhart 2010) and may further be excluded from shrimp trawls outfitted with TEDs.

Bycatch in the recreational shrimp fisheries is likely minimal, and effort in this sector has been difficult to quantify. While recreational fishermen holding a RCGL may use trawls up to 26 feet in length, creel limits, and area restrictions further limit their effort and bycatch. The use of non-trawl gears such as cast nets, seines, shrimp pots, and shrimp pounds are popular among recreational fishermen and have been shown to have minimal bycatch (Whitaker et al. 1991; McKenna and Clark 1993; Brown 2006; Sessions and Thorpe 2006).

See *Appendix 1: Shrimp Trawl Bycatch Assessment*, *Appendix 2.4: Managing Effort and Gear Modifications in the Shrimp Fishery to Reduce Bycatch* and *Appendix 2.3: Area Restrictions to Reduce Shrimp Trawl Bycatch in North Carolina* for more information on bycatch and discards of non-target species.

ECOSYSTEM PROTECTION AND IMPACTS

The growth and survival of shrimp within the habitats used are maximized when water quality parameters, such as temperature, salinity, and dissolved oxygen, are within optimal ranges. Additional information on these habitats including threats, water quality degradation and how these relate to the shrimp fishery are discussed below. Additional information can be found in the

North Carolina Coastal Habitat Protection Plan (CHPP), previous shrimp FMPs, various Division of Water Resources publications (NCDWQ 2000, 2008; NCDEQ 2016), and in the representation shown in Figure 13.

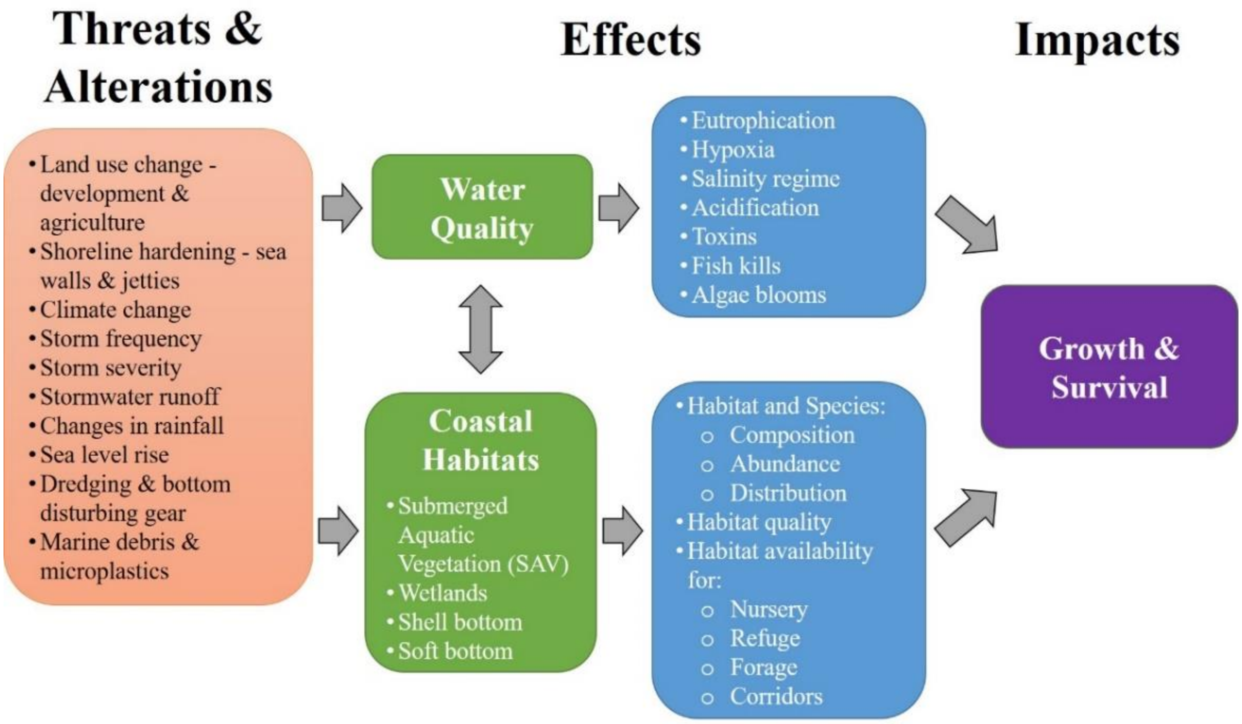

Figure 13. Effects of threats and alterations on water quality and coastal habitats and their ultimate impact on the growth and survival of various species.

FISHERY MANAGEMENT PLANS

State-managed species plans focus on current priority habitat issues specific to their species and target fisheries. The protection of habitat is reviewed in this plan's issue papers in relation to the shrimp fishery and how harvest areas may be adjusted to minimize fishery impacts to SAV, shell bottom, and Special Secondary Nursery Areas (SSNAs).

See *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas* and *Appendix 2.1 Management of Shrimp Trawling for Protection of Critical Habitats* for more nursery area and habitat information.

Coastal Habitat Protection Plan

The Fisheries Reform Act statutes require that a Coastal Habitat Protection Plan be drafted by the NCDEQ and reviewed every five years (G.S. 143B 279.8). The CHPP is intended as a resource and guide compiled by NCDEQ staff to assist the department, Marine Fisheries, Environmental

Management (EMC), and Coastal Resources (CRC) commissions in the development of goals and recommendations for the continued protection and enhancement of fishery habitats of North Carolina. The CHPP helps to ensure consistent actions among these commissions as well as their supporting NCDEQ divisions. The three commissions shall adopt rules to implement the Coastal Habitat Protection Plan in accordance with Chapter 150B of the General Statutes. Habitat recommendations related to fishery management can be addressed directly by the MFC. Habitat recommendations not under MFC authority (e.g., water quality management, shoreline development) can be addressed by the EMC and the CRC through the CHPP process.

The CHPP Source Document summarizes the economic and ecological value of coastal habitats to North Carolina, their status, and the potential threats to their sustainability (NCDEQ 2016). The Coastal Habitat Protection Plans and Source Document can be viewed and downloaded from: http://portal.ncdenr.org/web/mf/habitat/chpp/07-2020-chpp.

The CHPP is undergoing a mandated five-year review, with adoption planned in 2021. The priority issue, "Submerged Aquatic Vegetation (SAV) Protection and Restoration, with Focus on Water Quality Improvements" has implications for shrimp stocks. SAV is especially sensitive to water quality impairment from nutrient and sediment pollution and has been considered a "coastal canary", serving as a valuable bio-indicator of the overall health of coastal ecosystems. The primary mechanism to restore and sustain SAV is by improving water quality. The CHPP strategy for SAV involves modifying water quality criteria, such as chlorophyll-a levels and nutrient standards to reduce nutrient loading, to allow increased light penetration that is critical for SAV. This will not only benefit SAV but address other poor water quality impacts to marine resources. Another priority issue in the CHPP, "Wetland Protection and Restoration with a Focus on Nature-based Methods", also has direct implications for shrimp. Turner (1977) found a significant positive relationship between the size of wetlands and shrimp production. The positive relationship between wetlands and shrimp production was later shown to be affected by the extent of marsh edge and flooding duration (Minello et al. 2012). To protect and restore SAV and wetlands, which would benefit shrimp, mapping and monitoring of these habitats is critical to determine and provide direction on necessary protection or restoration actions. The priority issue "Habitat Monitoring to Assess Status and Regulatory Effectiveness" addresses more specifics regarding needed habitat monitoring.

One of the goals of the CHPP is to identify, designate, and protect Strategic Habitat Areas (SHAs). SHAs are specific locations of individual fish habitats or systems of fish habitats that have been identified to provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability or rarity. Division habitat staff have instituted additional sampling to validate the identified SHAs by employing the creation of a multi-metric index to further evaluate/validate the SHAs. Through this process habitat metrics will be analyzed and refined. A similar process will be used to evaluate the ecological condition of existing nursery areas and non-nursery areas.

In recent years, scientific literature has refined the concept of nursery areas. In earlier days, an entire estuary was initially considered a nursery area because of the occurrence of juveniles. But as ecosystem sciences advance, it has been found that in addition to density, other factors such as growth, predator protection, and movement out of the nursery into the adult habitat influence determination of nursery areas. Based on Beck et al. (2001), Dahlgren et al. (2006), and Peterson

(2003), nursery areas are a subset of juvenile habitat that contributes disproportionally more to the production of juveniles that recruit into a population than another area of similar size. Shallow habitats with structure, such as wetlands, SAV, and oyster reefs, provide more predator protection and food than soft bottom habitat, enhancing growth and survival (Lehnert and Allen 2002; Ross 2003; Grabowski et al. 2005). However, juvenile species require specific, optimal abiotic conditions, such as salinity and temperature, to maximize growth. Productive or optimal nursery areas occur where ideal abiotic factors, structured habitat, and landscape position overlap (Figure 14). While all waterbodies may have juvenile fish present at any given time, the combination of the above noted factors may not align, resulting in low nursery value (Beck et al. 2001; Peterson 2003). Shrimp trawling is restricted in the majority of these optimal nursery areas through habitat designations and area and gear restrictions.

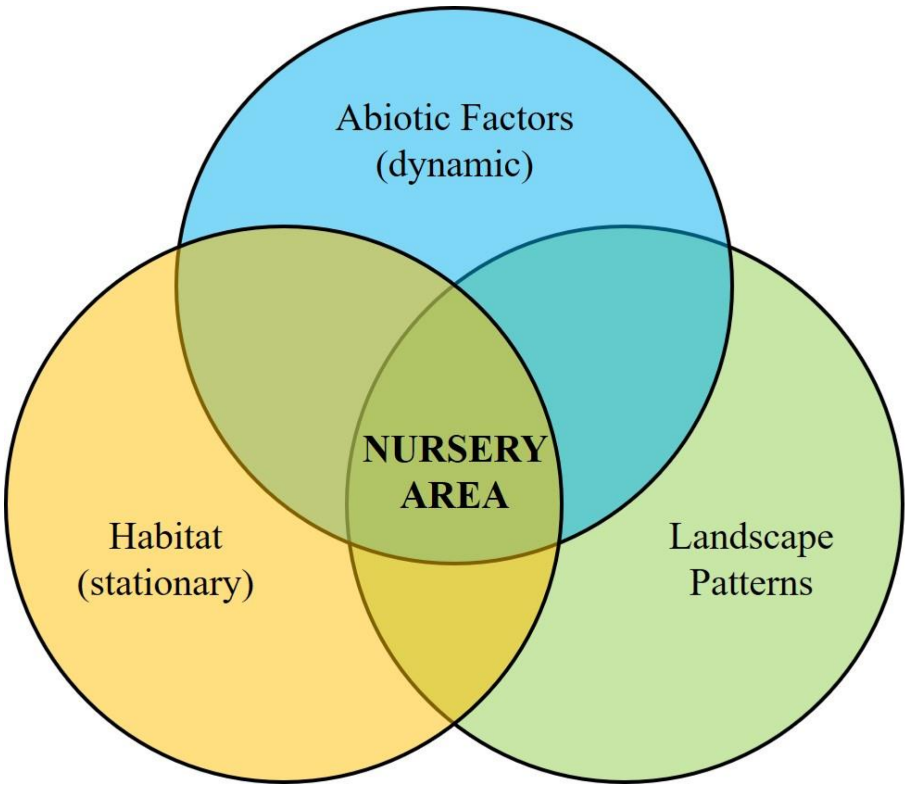

Figure 14. Depiction of the nursery area concept – the location where abiotic and habitat conditions, as well as the landscape setting are optimal for productivity. Abiotic factors – salinity, temperature, depth, currents; Habitat factors – wetlands, shell bottom, SAV, substrate; Landscape setting – geomorphology of the waterbody, proximity to inlets or adult habitat, habitat connectivity (adapted from Peterson 2003 and Beck et al. 2001).

Protecting existing coastal wetlands and SAV and taking steps to address losses is critical to maintaining production of shrimp. It is imperative the fishing community actively participate in the ongoing CHPP initiatives and add their voice to support the actions outlined in the CHPP.

Two objectives in this amendment relate directly to habitat protection of the CHPP:

- Promote the restoration, enhancement, and protection of habitat and environmental quality in a manner consistent with the CHPP.
- Develop a strategy through the CHPP to review current nursery areas and to identify and evaluate potential areas suitable for designation.

THREATS AND ALTERATIONS

Shrimp use a variety of estuarine and coastal ocean habitats and are found in most habitats identified by the CHPP (NCDEQ 2016). Adequate water quality is necessary to maintain the chemical properties of the water column required by shrimp, and the various habitats that support them (wetlands, submerged aquatic vegetation, shell bottom, and soft bottom). Human activities that degrade water quality or alter water flow can negatively impact shrimp growth or survival. Human activities and land use that increases nutrient loading can lead to prolonged periods of oxygen depletion in large areas of habitat (Jordan et al. 2018). Tidal creeks are considered critical nursery habitat for shrimp and can be particularly sensitive to land use and urban development (Sanger et al. 2015). As land modification occurs and impervious surfaces increase in areas adjacent to natural ecosystems, sedimentation, channelization, and toxin runoff events occur with greater frequency and severity. These events often become compounded since tidal creeks function as hydrological links to our estuaries (Sanger et al. 2015). As a result, low dissolved oxygen events, toxin contamination of sediments, and tidal creek channelization are probably the greatest water quality concerns for shrimp. For more information on other sources of water quality degradation, please refer to the CHHP (NCDEQ 2016).

Submerged aquatic vegetation (SAV), wetlands, shell bottom, and soft-bottom, including inlets and the ocean floor, are habitats of particular importance as nursery, refuge, foraging grounds, and movement corridors for shrimp (Williams 1955; Williams 1958; Weinstein 1979; Rulifson 1981; Bielsa et al. 1983; Murphey and Fonseca 1995; Steele 2002). Portions of these habitats have been degraded or lost over time by a variety of anthropogenic activities. Although it is difficult to quantify how, and to what extent, habitat degradation may alter annual shrimp populations, it remains important for management to understand the impacts of habitat degradation on other estuarine species that rely on similar habitat for survival.

The primary gear used in the shrimp fishery is shrimp trawls. Bottom disturbing fishing gear can impact ecosystem function through habitat degradation and is well documented (NCDMF 1999; NCDMF 2015; NCDEQ 2016). Extensive damage to SAV can occur from trawl doors that dig into the sediment and uproot plants. The dragged chain can cut or damage the above-ground leaves, but this does not always result in complete mortality (ASMFC 2000). Shrimp trawls can elevate turbidity, reducing water clarity needed for SAV growth and survival. Loss and damage to SAV is detrimental to the estuarine system due to the large diversity of fish and invertebrates that are dependent on it as a nursery and foraging area (NCDEQ 2016). Shrimp trawling can cause structural damage to oyster reefs (Berrigan et al. 1991). Similarly, shrimp trawling can cause structural damage to ocean hard bottom. This habitat, consisting of exposed limestone rock encrusted with live organisms such as coral, sponges, and other invertebrates, is critical for supporting reef fish communities.

RESEARCH NEEDS

The research recommendations listed below (in no particular order) are offered by the division to improve future management strategies of the shrimp fishery. They are considered high priority as they will help us to better understand the extent of bycatch from shrimp trawls, better manage the shrimp fishery, and meet the goal and objectives of the FMP. A more comprehensive list of research recommendations is provided in the FMP Update and Research Priorities documents reviewed annually and can be found at:
http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=33789156&name=DLFE-143144.pdf

- Conduct bycatch characterization work across all strata (for example: dominant species, season, areas, gear type, vessel type, number of nets/rigs, headrope length, TED position, etc.).
- Improve accuracy of self-reported license gear survey data or investigate other means of accurately obtaining shrimp fleet characteristics.
- Collect improved effort data (e.g., headrope length, number of nets, tow time, number of tows) to provide bycatch estimates based on actual time fished (or number of tows), rather than number of trips.
- Create and validate juvenile abundance indices for white and pink shrimp.
- Determine the cumulative impacts of shrimp trawl bycatch on individual species population dynamics and the ecosystem.

To gain a better understanding of the current magnitude and composition of discards in the shrimp trawl fishery, at sea observations are needed across all seasons, areas, and gears. Expanded characterization data across all segments of the fishery provides insight on gear selectivity and can aid in the development of new gear configurations to reduce bycatch. Due to the high variability of shrimp trawl bycatch data, additional information on tow duration and number of tows made during a trip is needed to expand discard estimates. Improved data on fleet characteristics and effort further allows fisheries managers to estimate total removals of bycatch species and produce more accurate stock assessments. Better estimates of shrimp trawl bycatch also allow managers to better understand how these removals alter the community structure of ecosystems. Fishery-independent monitoring programs need to be expanded to create juvenile abundance indices for white and pink shrimp to help managers estimate year class strength of all penaeid shrimp and further evaluate nursery areas.

SHRIMP AMENDMENT 2 MANAGEMENT STRATEGY

This section to be completed when the MFC selects their preferred management strategies that are taken out to review by the DEQ secretary, Gov Ops, AgNEER, and fiscal research division.

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APPENDICES

APPENDIX 1. SHRIMP TRAWL BYCATCH ASSESSMENT

The focus of this appendix is to discuss: 1) methods and data needed to estimate the amount of bycatch in the shrimp trawl fishery and 2) methods for estimating bycatch reduction and the impacts to common bycatch species.

Calculating Bycatch Estimates

Though the need is widely recognized, characterizing the nature, composition, and magnitude of bycatch in the shrimp trawl fishery has proven difficult (Diamond et al. 2000; Davies 2009; Wang et al. 2019). These difficulties are generally attributed to inadequate monitoring of many pertinent fishery characteristics including actual bycatch levels, effort of the directed fishery, variable fishing behavior, distribution and abundance of bycatch species, and the mortality rate of discarded species. The problem is exacerbated by the patchy distribution of fishing effort and juvenile finfish in both time and space. The amount of bycatch generally varies from tow to tow (and depends on many factors), with many tows having some bycatch and fewer tows with high bycatch (Diamond 2003; Fernandes et al. 2015).

Two methods are typically used to estimate shrimp trawl bycatch. One common method of estimating bycatch is the ratio method (fish:shrimp). While there are numerous ways to calculate the ratio, all forms of this method use some information about the ratio of kept and/or discarded bycatch to the target catch, usually at the tow, day, or trip level (i.e., per sample) caught by a gear or fishery and uses the reported landings of the target species multiplied by the ratio to estimate the total amount of bycatch (Diamond 2003; SEDAR 2014a). The main assumption with the ratio method is there is a direct linear relationship between the bycatch species and the target species, which often is not the case. For example, from division observer studies conducted from 2012 through 2017 (Brown 2015, 2016, 2017, and 2018), a linear regression was used to model the relationship between the observed weakfish and shrimp catch (Figure 1.1). The results showed a weak, positive linear relationship with a r^2 of 0.23. This means that only 23% of the variability in the catch data is explained by the linear relationship between weakfish and shrimp in the catch. Additionally, as more effective bycatch reduction devices (BRDs) are developed the relationship between the retained catch and the discarded catch will change (Wang et al. 2019). Another method used to estimate bycatch is the catch-per-unit-effort (CPUE) also called the bycatch-per-unit-effort (BCPUE) method. This method relies on fishery effort data and observer data or fishery independent proxy. Fishery independent data used as a proxy may help characterize bycatch, but it is important to determine gear type/comparability caveats of any fishery independent data used versus fishery dependent data (SEDAR 2014a).

A comparison among several ratio methods and a CPUE method found the four ratio methods tested were more biased than the CPUE method. Additionally, the four ratio methods were more influenced by the mean or variance of the catch, observer coverage, and correlation between the bycatch and target catch (Diamond 2003). Similarly, Edwards et al. (2015) found that model-based bycatch estimates were preferred because they showed less bias than ratio estimators. Carbonell et al. (2017) furthered the use of CPUE based estimates by incorporating environmental variables into their model to determine what environmental characteristics were related to higher rates of bycatch. However, in most cases the data needed to calculate reliable CPUE estimates for bycatch species is lacking. During the SEDAR (2014a) Procedural Workshop to evaluate shrimp data for assessment purposes and for bycatch estimation, several data requirements were identified based on methods used and can be found in Table 1.1.

The SEDAR (2014a) workgroup panel determined the ratio method was not the preferred method for bycatch estimation and noted it should be phased out as fishery effort time series become more reliable. The following issues were identified as potential problems with the ratio method:

- Difficult to separate fishing trends from fish population trends.
- Shrimp and fish populations are often on different trends. Unless there is a correlation between shrimp and the species of interest, should not use the ratio method.
- Should only use the ratio method when you have fishery-independent indices for shrimp and the fish species of interest so the ratio can be scaled.

The use of fishery-independent surveys to develop BCPUE estimates are not proxies alone for commercial BCPUE effort estimates but may be useful when combined with observer data. Fishery-independent surveys that use shrimping vessels and nets (e.g., SEAMAP) show much higher rates of BCPUE than observer programs, most likely due to differences in gear configuration, timing of sampling (day vs. night), and areas fished (randomly selected). However, fishery-independent indices may be correlated with commercial BCPUE, since both may reflect the abundance and availability of non-shrimp species. The Shrimp SEDAR Workgroup (2014a) recommended exploring the use of fishery-independent indices to tune BCPUE estimates where observer sample size is not adequate to produce year-specific BCPUE estimates.

Commercial shrimp trawl effort data currently collected through the division’s Trip Ticket Program include the number of trips and trip duration (not days fished) and may be insufficient to calculate reliable bycatch estimates depending on the desired effort metric for the fishery. The division and most other agencies do not typically collect more detailed effort data (e.g., number of fishing days, number of tows made during a trip or per day); although a few fisheries use logbooks to record effort metrics like tow time (Broadhurst et al. 2006; A. Bianchi, NCDMF, personal communication). Many of these more specific effort characteristics can be significant factors when estimating bycatch losses (e.g., mortality). Gear characteristics [i.e., number of nets, headrope length, BRD and turtle excluder device (TED) type and position, etc.] and strata (e.g., depth, season, area) are also important in calculating fishing effort (SEDAR 2014a).

While using the number of tows to represent effort rather than the number of trips or fishing days may be preferred it could present statistical problems. The variance in bycatch among tows in single day trips is likely less than for multi-day trips where tows are spread out over several days and likely over a broader spatial range. If the tows are not truly independent samples, then pseudoreplication would be a concern and result in imprecise variance estimates (Cochran 1977; Hurlbert 1984; Diamond 2003). Pseudoreplication occurs when samples are heavily dependent on each other. Since most trips in the North Carolina shrimp trawl fishery are single day trips (approximately 74% for otter trawls and 97% for skimmer trawls from 2012 through 2017; see Figure 2.4.5 in Appendix 2.4), there may be a high degree of covariance among tows in a trip. For example, if several tows are made in the same general area on the same day due to high catch rates of shrimp, the tows, and therefore the amount of bycatch caught, would not be considered independent samples, and the resulting bycatch estimates may be biased as the variance in bycatch would be underestimated (Diamond 2003). In this instance, using the number of trips or number of fishing days rather than the number tows may be preferred. Additionally, assuming there is less than 100% observer coverage, there would need to be an independent estimate of the average number of tows per trip available to use as an expansion factor for unobserved trips (Diamond 2003).

Data Collection Methods

There are several methods for collecting the data needed to estimate discards including onboard observers, logbooks, fishery-independent surveys, and fisher interviews. The best method for collecting data on bycatch species is through an onboard observer program (Kennelly 1995; Babcock et al. 2003; Suuronen and Gilman 2020; Curtis and Carretta 2020). Other methods, like the ratio method, have been shown to produce unreliable discard estimates (Surronen and Gilman 2019). Several studies give general guidance concerning the percentage of observer coverage needed to produce reliable bycatch estimates or methods for determining the percent coverage needed for the fishery or species of interest (Babcock et al. 2003; Borges et al. 2004; Curtis and Carretta 2020). SEDAR (2014a) recommended that observer coverage be increased with special attention to temporal and spatial factors such as seasons, day vs. night, and coverage of various fleets without compromising statistical design.

Although onboard observers are considered the gold standard for collecting reliable discard data, there are potential biases. Babcock et al. (2003) identified potential sources of bias such as non-random sampling (many programs are opportunistic and vessels volunteer to carry an observer) as well as changes in fishermen behavior in the presence of observers, among others. One way to check the latter is to compare catches of observed and unobserved trips. If the samples are unbiased, Babcock et al. (2003) suggests observer coverage levels of at least 20% for common species and 50% for rare species in fisheries with more than a few thousand trips per year (the NC shrimp trawl fishery averaged 7,248 trips per year from 2012 through 2017). Although, the actual level of coverage needed may be higher or lower depending on the size of the fishery, distribution of the catch and bycatch, and spatial stratification of the fishery.

Borges et al. (2004) evaluated optimum sampling levels in an observer program that considered both cost and precision objectives simultaneously and explored the dependence of sampling levels on both variables. They found that small budget reductions would result in marginal decreases in precision. However, increasing the precision by 50% would require unrealistic increases in sampling and associated program costs.

Due to the challenges of documenting rare-event bycatch, Curtis and Carretta (2020) developed a software package to help assess how much observer coverage is needed to estimate bycatch of these rare-event species. In the North Carolina shrimp trawl fishery these may include species such as sheepshead, black drum, Spanish mackerel, and sea turtles. The package predicts observer coverage performance based on three metrics: 1) the conditional probability of observing any bycatch given that bycatch occurred in the fishery and the probability of any bycatch in the total fishery effort, 2) the upper confidence limit for total bycatch when none is observed, and 3) precision of the bycatch estimate. The tool allows the user to explore how observer coverage targets may vary with total effort, bycatch per unit effort (BCPUE), and dispersion index.

The division does have limited shrimp trawl observer data that could be analyzed to help determine optimum observer coverage for the shrimp trawl fleet (Brown 2015, 2016, 2017, and 2018). Likely stratifications for an observer program would include gear, season, and area to ensure estimates are unbiased and representative of the fleet. Vessel size is also a factor that could be considered when determining how to allocate observer coverage. One decision point that would need to be made is which species or suite of species should be used to determine the optimum percent observer coverage for the shrimp trawl fishery. Some potential species to use for determining the appropriate amount of observer coverage include Atlantic croaker, spot, and weakfish. Another decision to be made would be the minimum level of precision desired for bycatch estimates as more precise estimates will require more observer coverage and therefore make the program more expensive to operate.

Observer Program Logistics

Starting an observer program specifically for the shrimp trawl fleet would be similar to the one currently in place for estuarine gill nets. Past observer studies of the shrimp trawl fleet were done on a voluntary basis but to produce reliable estimates of bycatch participation in the program would need to be mandatory for fishermen/vessel operators. From past observer studies (Brown 2015, 2016, 2017, and 2018), 2014 was the year with highest percent observer coverage at 1.7% where 149 out of 8,531 trip days were observed (Table 1.2). The cost for this study was approximately $150,000. To reach the 20% coverage recommended by Babcock et al. (2003), approximately 1,684 trip days would need to have been observed in 2014. The following paragraph outlines what would have been needed to achieve 20% observer coverage based on effort (trip days) from 2014.

The high number of trip days in the shrimp trawl fishery necessitates the need for additional staff (14 permanent and 14 temporary) due to the number of observed trip days that would be needed annually. Additional staff would likely consist of 13 permanent technicians, 14 6-month temporary technicians, and one permanent biologist. In addition to funds for new staff, operating funds would also be needed to purchase and maintain field and office equipment, cover travel costs for sampling operations, and other expenses. The total estimated cost is approximately $1.4 million (Table 1.3). Table 1.4 shows a breakdown of how many trip days per month on average each new staff member would need to observe to meet 20% observer coverage based on the number of trip days in 2014. The estimated number of trip days that would be observed annually is 1,728 and would have resulted in 20.3% observer coverage in 2014 (Table 1.5). Since 2014 had the lowest amount of trip days in the shrimp trawl fishery from 2012-2017, anywhere from 419 (2013) to 1,125 (2016) additional trip days would have to be observed to attain 20% observer coverage in those years. This increase in the number of observed trip days would likely further increase the cost of the observer program.

Logbook Program Logistics

A logbook program could be instituted in the commercial shrimp trawl fishery to gather additional effort information such as the number of tows per day or per trip, the total amount of headrope fished, and tow times for each tow. Implementing a commercial shrimp trawl fishery logbook program would be similar to the current North Carolina Trip Ticket Program (TTP). The TTP has two primary methods for reporting: paper forms and electronic submissions. It would make sense to also allow these two platforms for any potential logbook program (for example it would seem unfair to make all logbooks be reported electronically while trip tickets could still be reported via paper). The trip ticket templates for paper forms are specifically designed by fishery (shrimp, crab, finfish, etc.). Logbook templates may need to be designed for specific sectors of the shrimp trawl fishery and might need to be more specific than the trip ticket templates. For instance, it might be wise to have a specific logbook template for the shrimp otter trawl fishery and one for the skimmer trawl fishery, depending on the variables being collected. To report logbooks electronically, the software should be designed to allow for fishermen who might be federally permitted to use that same platform to report to the state and the National Marine Fisheries Service (like what is in place for seafood dealers who are federally permitted).

The reporting frequency for any logbook program would also need to be considered. The TTP has a requirement for data to be turned in by the 10th of the following month. For a logbook program, a similar requirement would need to be put in place to track compliance (making sure logbooks are coming in when they are supposed to). Having logbooks submitted by the 10th of the following month would also work well because the industry and staff are already used to that schedule.

For the NCDMF Commercial Statistics Program to successfully implement a commercial shrimp trawl fishery logbook program more resources and staff would be needed. In license year 2020, there were 672 seafood dealer licenses issued (NCDMF 2020). Although not all seafood dealers reported trip tickets, all dealers were tracked for compliance purposes (seafood dealers who did not have any business still have to report to the TTP that they do not have any activity by the 10th of the month). In comparison, there were 350 to 450 fishing licenses with commercial shrimp trawl (otter and skimmer) landings in 2018 and 2019 (NCDMF 2020). Although the number of commercial fishing licenses is about 60% of the number of seafood dealers, compliance tracking would be more labor intensive because of the mobile nature of commercial fishermen compared to seafood dealers.

The data collected through a logbook program would be entered into the NCDMF Fisheries Information Network. For this to happen, new data tables would need to be developed as well as a new set of interface screens for division staff to enter the data. A process for submitting logbooks electronically would need to be developed as would a means to link logbook entries to their associated trip ticket.

The estimated cost to launch a commercial shrimp trawl fishery logbook program in North Carolina would be steep. The TTP spends about $15,000 a year to print trip tickets and another $10,000 a year for a maintenance contract to support the software program used by our seafood dealers. Assuming a logbook would be a three-part form (as opposed to a four-part form used for trip tickets) and about two-thirds of commercial shrimp trawl fishermen would report by paper (similar to what we see with seafood dealers), it is estimated that logbook printing would be roughly $11,250 a year. It is also reasonable to assume the software maintenance contract would increase because it would increase the number of users by 1.5 times (~$5,000). There would also be additional cost to configure the current software for a logbook program which is estimated to cost about $60,000. The operational costs of the program would also need to be considered (postage, supplies, computers, etc.) and are estimated at $46,500. The additional staff needed to administer the program would include one data entry clerk ($25,000), one data control clerk ($31,000), two port agents ($64,000), and one biologist/analyst ($41,000). The total estimated cost for a commercial fisheries logbook program for North Carolina is $283,250 (Table 1.6). There is also the additional burden to fishermen to consider as they would have to spend additional time recording, verifying, and submitting logbook entries. In some states where logbooks have already been implemented, fisheries managers are scaling back these efforts and relying more on dealer reporting due to the cost of their logbook program (D. Lupton, NCDMF, personal communication).

Quantifying Bycatch Reductions

The division does not have the minimum data necessary to produce reliable absolute estimates of shrimp trawl bycatch and hence cannot quantify potential reductions in bycatch from various management actions. However, proxies may be examined to give a reasonable estimates of the potential reduction in bycatch for some management measures under consideration. To serve as a proxy for potential bycatch reductions for some area closures under consideration in Amendment 2, the division could look at data from one or more fishery-independent surveys as these provide useful information on the species composition and abundance on the fishing grounds (Kennelly 1995). For example, one method for potentially evaluating proposed closed areas in Pamlico Sound would be to use data from the division’s Pamlico Sound Survey to come up with a proxy estimate for potential bycatch reductions due to a proposed area closure in Pamlico Sound. This could be done by determining the percent abundance of a particular species typically caught within the proposed closed area compared to the entire area sampled by the survey. While this is not a true estimate of bycatch reduction it would give managers some idea about the potential effectiveness of management measures in achieving some level of bycatch reduction. This would have to be done once a potential closed area was identified and a recent year or group of years would need to be chosen to estimate past abundance and distribution, which can be highly variable. This also assumes the species of interest makes up approximately the same percentage of the catch in the Pamlico Sound Survey as it does in the commercial fishery which may not be the case due to differences in gear (e.g., mesh size, BRDs, TEDs), area fished (depth), time of day fished, and time of year fished (Pamlico Sound Survey only samples in June and September). A similar approach was used by Gücü (2012) to model potential reductions in bycatch based on depth and season closures in the Mediterranean Sea. The study found higher amounts of discards would be expected to occur in shallower depths during certain times of year and that limiting effort in those areas and times discard losses could be mitigated.

Quantifying Impacts of Reducing Bycatch on Bycatch Species

Quantifying the impacts of reducing bycatch has proven to be a difficult task. Regardless of how large or small the bycatch estimate is for a species the number is meaningless in the absence of a population estimate from a stock assessment (Kennelly 1995). While large populations may be able to withstand large amounts of bycatch losses, a small population may be unable to withstand even small losses (Diamond 2003). Further the life history strategy of a species may also affect its ability to withstand varying levels of bycatch losses. Species that mature quickly and produce large numbers of young (r-selected species), such as spot, may be able to accommodate higher levels of discards than a species that matures slowly and produces few young (k-selected species), such as Atlantic sturgeon. Even when a stock assessment is available and bycatch estimates are incorporated, reducing mortality from bycatch alone may not have the expected outcome if the bycatch species/life stage is subject to high rates of natural mortality (Kennelly 1995), as was the case with Gulf of Mexico red snapper (see below; Galloway et al. 2017; Galloway et al. 2020; Cowan 2010). To properly estimate the impact of bycatch losses for any species, estimates of natural mortality, biomass, length at age, and estimates of discard mortality are needed (Kennelly 1995). Accounting for discard losses is vital for fisheries managers to set accurate harvest limits. In fisheries where discard losses are a large portion of the catch, including or excluding discard losses can impact the yield, effort, and biomass at Maximum Sustainable Yield (MSY) as does the survival rate of the discarded catch (Guillen et al. 2014). Additionally, to gauge any potential positive population impacts of reducing bycatch, a stock assessment is needed that produces estimates of stock size through time to monitor population size prior to and after management action was taken. Given the life history and coast-wide distribution of many bycatch species (e.g., Atlantic croaker, spot, weakfish) any benefits to inshore fisheries may not be realized even with reductions in bycatch.

Weakfish in the Atlantic

Weakfish is managed as a single cost-wide stock with all states from Massachusetts through Florida having a declared interest in weakfish. The first stock assessment for weakfish occurred in 1991 and found the stock was overfished and overfishing was occurring (Vaughn et al. 1991). Management responded by requiring all states to 1) reduce exploitation (mortality) of weakfish by 15 to 25% in 1992, 2) implement minimum size limits of 10 inches in 1992, 11 inches in 1993, and 12 inches in 1994, 3) further reduce exploitation by 25% in 1993 and 1994, 4) South Atlantic states reduce shrimp trawl by catch of weakfish by 50% by 1994, and 5) implement mesh size restrictions for gill nets and finfish trawls to achieve a 75% escapement rate of undersized weakfish (Seagraves 1991). To comply with Amendment 1, North Carolina 1) required the use of BRDs beginning in 1992, 2) closed the ocean flynet fishery south of Cape Hatteras in 1994, 3) implemented minimum size limits for weakfish in 1992, and 4) implemented minimum mesh size requirements for gill nets and flynets in 1992. However, due to poor compliance from most states, Amendment 2 was adopted in 1994 (ASMFC 1994). The purpose of Amendment 2 was to allow full implementation of the management strategy in Amendment 1 under the newly passed Atlantic Coastal Fisheries Cooperative Management Act. The weakfish stock was assessed again in 1994 and found the stock was still overfished and overfishing was occurring (Gibson 1995). Amendment 3, adopted in 1996, required states to implement a 12-inch minimum size limit, set minimum mesh size requirements for gill nets and fish trawls that retained less than 25% of weakfish under 12 inches, and to strengthen BRD certification requirements. These measures were meant to reduce fishing mortality to F=0.50 by 2000 (Lockhart et al. 1996).

A new stock assessment for weakfish was completed in 2002 (Kahn 2002). The assessment showed that fishing mortality in 2000 was below the target of F=0.50 and that stock biomass had increased above the $SSB_{threshold}$ of 14,400 metric tons. The stock assessment was updated in 2006 (ASMFC 2006) and while the stock assessment was not formally accepted key points from the assessment were accepted for management use, they were 1) the stock is declining, 2) total mortality is increasing, 3) there was not much evidence for overfishing, 4) something other than fishing mortality was causing the decline in the stock, and 5) there is a strong chance that regulating the fishery would not, in itself, reverse stock decline.

In 2009 the stock was again assessed, and the results of the assessment indicated weakfish abundance had declined markedly, total mortality was high, non-fishing mortality had increased, and the stock was in a depleted state (NEFSC 2009). The weakfish stock was depleted and at an all-time low of 10.8 million pounds (4,899 metric tons). At that stock size, fishery removals (landings and dead discards combined) represented a significant proportion of the remaining biomass. While the decline in the stock primarily resulted from a change in the natural mortality of weakfish, it was further exacerbated by continued removals by the commercial and recreational fisheries. Natural mortality had risen substantially since 1995, with factors such as predation, competition, and changes in the environment having a stronger influence on recent weakfish stock dynamics than fishing mortality. Given the high natural mortality levels, stock projections indicated the stock was unlikely to recover rapidly, even under a harvest moratorium (NEFSC 2009).

A new stock assessment model was used in 2016 to assess the weakfish stock and found the stock was still depleted although there were some positive signs in SSB in the last few years of the assessment and that natural mortality had risen to levels that were preventing the stock from recovering (ASMFC 2016). With the advent of revised recreational landings estimates, the assessment was updated in 2019 (ASMFC 2019). The results differed little from the 2016 assessment, showing the stock was still depleted though there was a slight increase in SSB in the last few years.

Atlantic Croaker in the Gulf of Mexico and South and Mid-Atlantic Bights

Diamond et al. (2000) used matrix models to explore the population-level impacts of shrimp trawl bycatch on Atlantic croaker populations in the Gulf of Mexico and the South and Mid-Atlantic bights and explored tradeoffs between the directed adult fisheries and bycatch mortality in shrimp trawls. Based on a previous study (Diamond et al. 1999) their a priori assumptions were 1) both stocks were declining in abundance, 2) both populations were more sensitive to first-year survival than any adult year, 3) mortality in the late juvenile stage, which is primarily bycatch mortality, had a greater effect on population growth rates than mortality during any other first-year stage, and 4) Atlantic croaker in the Gulf were more affected by bycatch mortality than in the Atlantic because of higher bycatch levels in the Gulf.

Their analysis showed both populations were more sensitive to adult survival than first-year survival. Bycatch mortality of late juveniles was not the most important factor affecting either population. Both populations were most sensitive to ocean larva mortality. In the Atlantic, this was followed by early juvenile and adult mortality. Although, bycatch mortality did have a negative impact on population growth rates and they estimated that reducing late juvenile or adult mortality by 5% in the Atlantic would reverse the modest population decline seen in their model. They speculated that the BRDs currently being used in the fishery would achieve the 5% reduction in mortality.

South Carolina Trawl Net Closure

The inside waters of South Carolina's sounds and bays were consistently opened to trawling beginning in 1952. However, through time, conflict between large shrimping vessels and small shrimping vessels on whether the sounds and bays should remain open continued through the 1960s and 1970s. Small vessels preferred the sounds and bays remain open while the large vessels preferred them closed. Mid-sized vessels were evenly divided on the issue. By the 1980s, recreational fishermen and environmentalists became involved and asked for permanent closure of the sounds and bays to protect recreationally important finfish such as spotted sea trout and red drum (Whitaker 1989). Bearden et al. (1985) examined all available information and provided a report concluding the policy of opening the sounds and bays had not increased or decreased the overall physical or economic yield of shrimp. It also indicated there was negligible impact of trawling on habitat, crabs, and fish in the sounds and bays.

However, at the request of shrimpers, recreational fishermen, and environmentalists, the SC General Assembly closed the three sounds and one bay to commercial trawling for 1986 and 1987. The Crustacean Management section of the South Carolina Wildlife and Marine Resource Department (now the South Carolina Department of Natural Resources) set out to assess the closure through a fall trawl survey in the sounds and bays and a shrimp tagging program. Although it was pointed out that a two-year closure was too short to properly assess, it was concluded that:

1. Very few spotted seatrout and red drum were caught by trawling in the sounds and bays of SC.
2. No evidence trawling in the sounds or along the ocean beaches caused any long-term decreases in finfish populations.
3. Loss of forage species was more difficult to assess but believe that serious impacts would have been realized long ago.
4. Shrimp were consistently larger in areas outside of the sounds compared to shrimp size inside the sounds. This may represent a greater economic yield but if there are greater losses from natural mortality before moving into the ocean, economic yield could decrease despite the increase in size.
5. It was concluded that shrimp and fish stocks had not been negatively affected from a biological standpoint by commercial shrimp trawling.

Gulf of Mexico Red Snapper

In the initial stock assessment (1995) for Gulf of Mexico red snapper, natural mortality of juveniles was thought to be low, and the assessment concluded approximately 80% of total juvenile mortality was from bycatch in the shrimp trawl fishery and was the reason for the stock decline (Goodyear 1995; Galloway et al. 2017). Management responded by requiring shrimp trawl bycatch mortality be reduced by 50% with no corresponding reductions from the directed fisheries (recreational and commercial). The reduction in shrimp trawl bycatch mortality was to be achieved by requiring the use of BRDs.

A new stock assessment conducted in 2005 determined the stock was still overfished because the BRDs did not meet the target reduction and harvest in the directed fisheries remained unchanged under the false assumption the bycatch reduction target was being met (SEDAR 2005; Galloway et al. 2017). The 2005 stock assessment also produced new estimates of juvenile mortality, attributing 33% of total juvenile mortality to shrimp trawls (much less than the initial stock assessment estimate of 80%) and natural mortality accounted for 67% of total juvenile mortality. Management again responded by not reducing harvest in the directed fisheries and instead opted to update BRD certification procedures (GMFMC 2006). A year later effort controls were established in the shrimp trawl fishery to reduce shrimp trawl effort in the western Gulf of Mexico by 74% in depths of 10-30 fathoms from 2001 to 2003 levels. In concert with this step, the quota for directed fisheries was reduced from 9.12 million pounds to 6.5 million pounds (GMFMC 2007) and was further reduced to 5 million pounds in 2008 and 2009. Only once harvest in directed fisheries was reduced did the stock begin to recover (Galloway et al. 2017). This should not be interpreted to mean that reducing bycatch mortality from shrimp trawls is unnecessary; however, it is likely not the only remedy needed to recover a depressed stock and, in some cases, reducing bycatch mortality may increase mortality from another source (natural mortality in the case of Gulf of Mexico red snapper).

Summary

Below are few summary points to consider:

- The CPUE method is preferred for calculating bycatch estimates as the ratio method is unreliable and prone to bias because it assumes a proportional relationship between the bycatch species and the target species.
- The level of observer coverage needed to attain reliable long-term estimates of shrimp trawl discards is likely high, as is the cost.
- In some instances, fishery-independent survey data may be used to provide guidance on potential bycatch reductions.
- Quantifying the impact of shrimp trawl bycatch on a species is difficult without an approved stock assessment for the species of interest.
- Reducing shrimp trawl bycatch alone is often not enough to recover an overfished stock.

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Tables

Table 1.1. Commercial shrimp bycatch estimation methods and corresponding data requirements (X) identified by the SEDAR Shrimp Workshop Panel (SEDAR 2014a).

	BYCATCH ESTIMATION METHODS		
Data Type	CPUE Method (King Mackerel; SEDAR 2014b)	CPUE Method (Sharks; SEDAR 2015)	Ratio Method (Atlantic Croaker Stock Assessment; ASMFC 2010)
Fishery Effort (Depth x Season x Strata x Gear Characteristics)	X	X	
Shrimp Catch	X (used to estimate effort)	X	X
Kept Bycatch/Fish			X (if available)
Discarded Bycatch/Fish	X (mortality estimate)	X	X
Fish age/length	X (Age 0 assumed)	X	X (Age 0 check assumption)
Fish BCPUE (observer CPUE)	X	X	
Fishery Independent CPUE)	X	X	
Minimum Data Requirement	Should be defined	Should be defined	Should be defined
BRD/TED-Type & Impact	X (need paired research)	X	X

X=Required

Table 1.2. Summary of observer coverage percentages using trip days for the North Carolina shrimp trawl fishery from NCDMF bycatch characterization studies (Brown 2015, 2016, 2017, 2018). Fleet trip days data from the NCDMF Trip Ticket Program. *Trip days includes shrimp trawl trips with durations of 1-6 days. Longer trips were excluded from the analysis and constituted 1.1% of the trips for 2012-2017.

Study Year	Study Months	Area	Gear	Observed Fishing Days	Total Trip Days (Sample Period)	Total Annual Trip Days	Percent Coverage (Sample Period)	Annual Percent Coverage
2012	Aug-Dec	Pamlico Sound	Otter Trawl	29	2,602	4,851	1.1	0.6
		Other Inshore	Otter Trawl	20	1,234	2,819	1.6	0.7
		Ocean	Otter Trawl	28	1,557	2,209	1.8	1.3
		All	*Otter Trawl*	*77*	*5,393*	*9,879*	*1.4*	*0.8*
	None	Pamlico Sound	Skimmer Trawl	0	3	6	0.0	0.0
		Other Inshore	Skimmer Trawl	0	957	1,092	0.0	0.0
		Ocean	Skimmer Trawl	0	0	0	0.0	0.0
		All	*Skimmer Trawl*	*0*	*960*	*1,098*	*0.0*	*0.0*
		Total	**All Trawls**	**77**	**6,353**	**10,977**	**1.2**	**0.7**
2013	Jan-Dec	Pamlico Sound	Otter Trawl	39	4,856	4,856	0.8	0.8
		Other Inshore	Otter Trawl	14	2,577	2,577	0.5	0.5
		Ocean	Otter Trawl	43	2,091	2,091	2.1	2.1
		All	*Otter Trawl*	*96*	*9,524*	*9,524*	*1.0*	*1.0*
	None	Pamlico Sound	Skimmer Trawl	0	35	35	0.0	0.0
		Other Inshore	Skimmer Trawl	0	1,177	1,177	0.0	0.0
		Ocean	Skimmer Trawl	0	0	0	0.0	0.0
		All	*Skimmer Trawl*	*0*	*1,212*	*1,212*	*0.0*	*0.0*
		Total	**All Trawls**	**96**	**10,736**	**10,736**	**0.9**	**0.9**
2014	Jan-Dec	Pamlico Sound	Otter Trawl	69	4,362	4,362	1.6	1.6
		Other Inshore	Otter Trawl	13	1,947	1,947	0.7	0.7
		Ocean	Otter Trawl	67	1,494	1,494	4.5	4.5
		All	*Otter Trawl*	*149*	*7,803*	*7,803*	*1.9*	*1.9*
	None	Pamlico Sound	Skimmer Trawl	0	23	23	0.0	0.0
		Other Inshore	Skimmer Trawl	0	705	705	0.0	0.0
		Ocean	Skimmer Trawl	0	0	0	0.0	0.0
		All	*Skimmer Trawl*	*0*	*728*	*728*	*0.0*	*0.0*
		Total	**All Trawls**	**149**	**8,531**	**8,531**	**1.7**	**1.7**
2015	Jan-Aug	Pamlico Sound	Otter Trawl	23	3,520	5,794	0.7	0.4
		Other Inshore	Otter Trawl	15	1,627	2,308	0.9	0.6
		Ocean	Otter Trawl	28	621	2,358	4.5	1.2
		All	*Otter Trawl*	*66*	*5,768*	*10,460*	*1.1*	*0.6*
	Jan-Dec	Pamlico Sound	Skimmer Trawl	5	39	39	12.8	12.8
		Other Inshore	Skimmer Trawl	57	960	960	5.9	5.9
		Ocean	Skimmer Trawl	0	0	0	0.0	0.0
		All	*Skimmer Trawl*	*62*	*999*	*999*	*6.2*	*6.2*
		Total	**All Trawls**	**128**	**6,767**	**11,459**	**1.9**	**1.1**
2016	Jan-Dec	Pamlico Sound	Otter Trawl	9	5,783	5,783	0.2	0.2
		Other Inshore	Otter Trawl	16	2,729	2,729	0.6	0.6
		Ocean	Otter Trawl	27	3,853	3,853	0.7	0.7
		All	*Otter Trawl*	*52*	*12,365*	*12,365*	*0.4*	*0.4*
	Jan-Dec	Pamlico Sound	Skimmer Trawl	0	119	119	0.0	0.0
		Other Inshore	Skimmer Trawl	20	1,217	1,217	1.6	1.6
		Ocean	Skimmer Trawl	0	0	0	0.0	0.0
		All	*Skimmer Trawl*	*20*	*1,336*	*1,336*	*1.5*	*1.5*
		Total	**All Trawls**	**72**	**13,701**	**13,701**	**0.5**	**0.5**
2017	July-Dec	Pamlico Sound	Otter Trawl	8	6,259	6,440	0.1	0.1
		Other Inshore	Otter Trawl	10	1,983	2,685	0.5	0.4
		Ocean	Otter Trawl	2	2,576	4,353	0.1	0.0
		All	*Otter Trawl*	*20*	*10,818*	*13,478*	*0.2*	*0.1*
	July-Dec	Pamlico Sound	Skimmer Trawl	0	275	287	0.0	0.0
		Other Inshore	Skimmer Trawl	15	473	494	3.2	3.0
		Ocean	Skimmer Trawl	0	5	5	0.0	0.0
		All	*Skimmer Trawl*	*15*	*753*	*786*	*2.0*	*1.9*
		Total	**All Trawls**	**35**	**11,571**	**14,264**	**0.3**	**0.2**

Table 1.3. Estimated cost for implementing a commercial shrimp trawl observer program for the NC shrimp trawl fishery.

Category	Number of Staff	Unit Cost	Estimated Cost
Observer Field Supplies	28	$2,000	$56,000
Travel (Food, Lodging, Mileage)	28	$17,808	$498,624
Other	28	$1,500	$42,000
Staff			
Permanent Technician	13	$36,000	$468,000
6-month Temporary Technician	14	$20,000	$280,000
Biologist	1	$45,000	$45,000
Total			$1,389,624

Table 1.4. Estimated number of trip days observed by position per month and year, number of trip days observed per year by position type, and total number of trip days observed per year for the NC shrimp trawl fishery.

Position Type	Number of Trip Days Observed / Person / Month	Total Number of Trip Days Observed / Person / Year	Total Number of Staff	Total Number of Trip Days Observed / Year / Position Type
Permanent Technician	7	84	13	1,092
6-month Temporary Technician	7	42	14	588
Permanent Biologist	4	48	1	48
Total Number of Trip Days Observed/Year				1,728

Table 1.5. Estimated observer coverage for proposed level of observed trip days and number of trip day observations needed to attain 20% observer coverage for the NC shrimp trawl fishery, 2012-2017.

Year	Number of Trip Days	Proposed Observed Trip Days	Percent Observer Coverage	Observed Trip Days Needed for 20% Observer Coverage
2012	10,977	1,728	15.7	2,195
2013	10,736	1,728	16.1	2,147
2014	8,531	1,728	20.3	1,706
2015	11,459	1,728	15.1	2,292
2016	13,701	1,728	12.6	2,740
2017	14,264	1,728	12.1	2,853

Table 1.6. Estimated cost for implementing a commercial logbook program for the NC shrimp trawl fishery.

Category	Number of Staff	Unit Cost	Estimated Cost
Logbook Printing	-	-	$11,250
Software Maintenance Contract	-	-	$5,000
Software Configuration	-	-	$60,000
Operational Cost	-	-	$46,000
Staff			
Data Entry Clerk	1	$25,000	$25,000
Data Control Clerk	1	$31,000	$31,000
Port Agent	2	$32,000	$64,000
Biologist	1	$41,000	$41,000
Total			$283,250

Figures

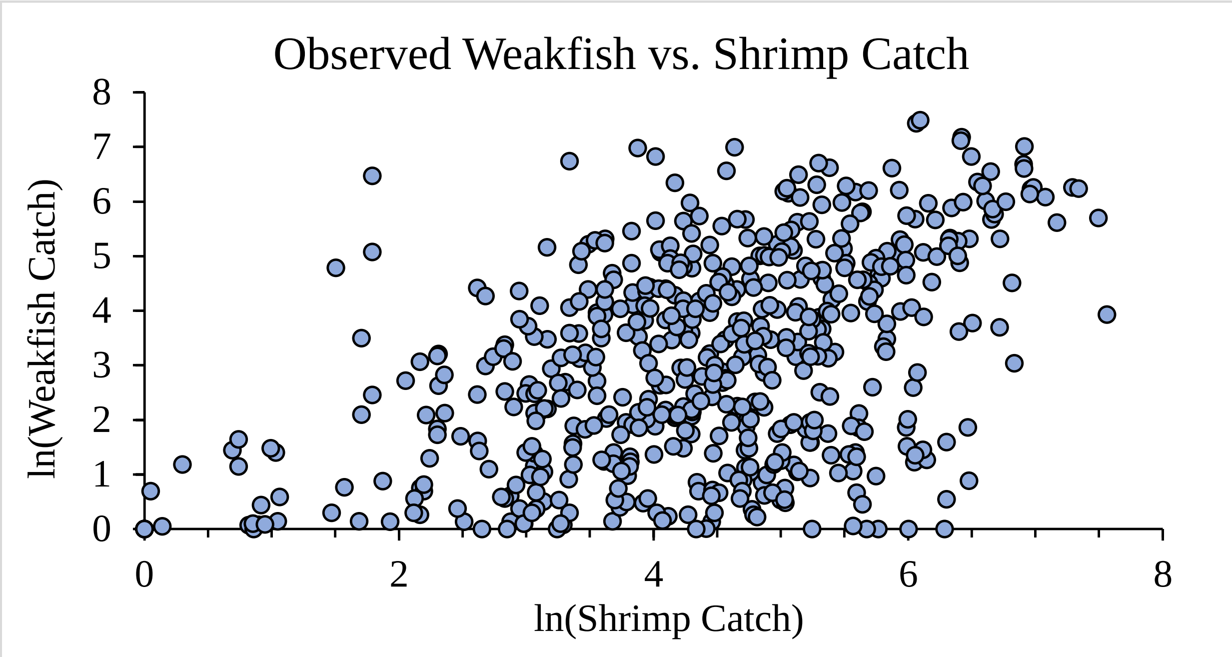

Figure 1.1. Plot of the natural log (ln) of weakfish (kg) versus the ln of shrimp (kg) in observed shrimp trawl catches, 2012-2017.

APPENDIX 2. ISSUE PAPERS

APPENDIX 2.1. MANAGEMENT OF SHRIMP TRAWLING FOR PROTECTION OF CRITICAL SEA GRASS AND SHELL BOTTOM HABITATS

I. ISSUE

Providing additional protections for critical sea grass and shell bottom habitats through shrimp trawl area closures.

II. ORIGINATION

The North Carolina Division of Marine Fisheries (NCDMF) Shrimp Plan Development Team (PDT) and the public.

III. BACKGROUND

North Carolina's estuarine system is the largest of any coastal state along the eastern Atlantic seaboard and encompasses a diverse aquatic system of estuarine rivers, creeks, large sounds, and inlets totaling over 2.2 million acres (Deaton et al. 2010; NCDMF unpublished data). Framed by a chain of low-lying barrier islands from Virginia to the Cape Fear River, these habitats include intertidal and subtidal oyster reefs and extensive submerged aquatic vegetation (SAV) beds which provide a litany of ecosystem services, including shoreline stabilization, storm water filtration, and critical habitat for a variety of juvenile finfish and shellfish species. Furthermore, this estuarine system provides North Carolina access to a variety of commercially and recreationally important fisheries, including shrimp, blue crab (*Callinectes sapidus*), oysters (*Crassostrea virginica*), southern flounder (*Paralichthys lethostigma*), spotted seatrout (*Cynoscion nebulosus*), and red drum (*Sciaenops ocellatus*). In addition, the estuarine waters of North Carolina provide important habitat for many interjurisdictional managed species including Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), and weakfish (*C. regalis*). Given these characteristics, it is clear the habitats which make up North Carolina's estuarine system hold tremendous ecological, economic, and social value for the citizens of North Carolina and warrant management measures that guarantee their persistence.

While there are several major threats to the overall health of these habitats (i.e., pollution, coastal development, climate change, etc.), one of particular concern in North Carolina is the use of bottom disturbing fishing gears (i.e., trawls and dredges). Bottom trawls are conical nets pulled behind vessels along the benthos and are the primary fishing gear used to harvest shrimp (see *Description of the Fisheries* section of Amendment 2 for full description of gear). The potential environmental impact of using this gear has been extensively studied in a variety of habitat types ranging from flat sand and mud bottoms to structured habitats, including piled boulders, live bottom, seagrass, kelp beds, and coral reefs (Dorsey and Pederson 1998; Auster 1998; Hiddink et al. 2017; Sciberras et al. 2018). Findings from these studies suggest mobile fishing gear can significantly reduce habitat complexity by smoothing the bottom and removing structures that provide essential refuge and resources to a variety of benthic predator and prey species (Dorsey and Pederson 1998). Trawling also increases turbidity in many areas which can slow the growth of primary (algae and plants) and secondary producers (organisms that consume other organisms), limit nutrient regeneration, and disrupt the feeding relationships of all organisms within the ecosystem (the food web).

The magnitude of trawling disturbance is highly variable, ranging from no apparent effect to the complete elimination of some species, and can introduce long-term changes within the benthic community. The ecological effect of trawling depends upon site-specific characteristics of the ecosystem such as bottom type (sand, mud, shell, grass, reef, etc.), water depth, type of animal community (small vs. large sized species, short-lived vs. long-lived species, mobile vs. immobile species), type of trawl employed, and the intensity and duration of trawling and natural disturbances. The rate of recovery for benthic communities following bottom fishing disturbance events is also highly dependent on the habitat type. In other words, communities typically inhabited by sessile organisms with slow growth rates tend to also exhibit slow recovery rates (i.e., coral reefs, oyster reefs, etc.) following a disturbance. Conversely, habitats that experience consistent disturbance from storm events, wave action, and high tidal flow are commonly inhabited by fast growing, short-lived species which are generally capable of rapid recovery (NRC 2002).

Trawling Effects on Shell Bottom

For a complete review of habitat requirements, distribution, ecological role and functions, fish use, biological functions and status of shell bottom see the North Carolina Coastal Habitat Protection Plan Source Document (NCDEQ 2016).

Shell bottom is estuarine intertidal or subtidal bottom composed of surface shell concentrations including living or dead oysters (*Crassostrea virginica*), hard clams (*Mercenaria mercenaria*), or other shellfish (Street et al. 2005; NCDEQ 2016). Oyster rocks form a complex three-dimensional structure of accumulating shells and oysters over the course of many years and provide critical habitat for the settlement of larval oysters, sessile filter feeding organisms, and refuge for small fish and invertebrates. Shell bottom is widely recognized as essential fish habitat (EFH) for oysters and other reef-forming mollusks (ASMFC 2007). Shell bottom also provides ecosystem resilience by improving water quality through filtration (ASMFC 2007; Wall et al. 2008).

The more complex the habitat structure, the more susceptible the habitat is to disturbance by mobile bottom fishing gear (Auster 1998). Shell bottom is a complex habitat that is affected by both oyster dredges and otter trawls. Trawling over oyster reefs negatively impacts live shell bottom habitat by disturbing the structure of the reefs, reducing and scattering the upper layers of shell with the movement of trawl doors or chain as the gear is fished over the structure (NCDMF 2001; Street et al. 2005). In addition, trawling can significantly reduce epifaunal organisms in shell beds and recovery can take an extended period (Cook et al. 2013).

Shellfish rehabilitation and cultch planting has continuously occurred in North Carolina since the early 1900s. To date, millions of bushels of shell and fossil rock have been deposited into coastal estuaries from Dare to Brunswick counties. In most cases, cultch planting sites are not re-enhanced, rather new sites in new areas are built every year; resulting in thousands of sites in almost every suitable water body along the coast with reliable records for cultch planting dating back to 1981, detailing 1,648 reef sites (J. Peters, NCDMF; personal communication). For a complete review of the history of shellfish rehabilitation and cultch planting in North Carolina, see the North Carolina Oyster Fishery Management Plan (NCDMF 2001) and Amendment 4 of the North Carolina Oyster Fishery Management Plan (NCDMF 2017).

Oyster sanctuaries are protected under Rule 15A NCAC 03K .0209 and delineated in 15A NCAC 03R .0117, which prohibits oyster harvest and use of trawls, long haul seines, and swipe nets therefore promoting growth and enhancing survivability of large oysters within the sanctuaries (Table 2.1.1). Oyster sanctuaries under construction but not yet incorporated into 15A NCAC 03R .0117 can be protected under Rule 15A NCAC 03H .0103 and 15A NCAC 03K .0103 through proclamation authority.

Ongoing efforts to identify suitable areas for oyster restoration may include cultch planting and other oyster protections in areas where trawling currently occurs. State posted oyster plantings are protected from any type of trawling or seining when designated as shellfish management areas under rule 15A NCAC 03K .0103. Rule 15A NCAC 03K .0103 gives the Fisheries Director proclamation authority to designate shellfish management areas in areas with suitable environmental conditions necessary for shellfish growth or areas that have shellfish populations or shellfish enhancement projects. Within shellfish management areas, it is unlawful to use trawl nets, long haul seines or swipe nets. These areas must be marked with signs or buoys.

Posting of natural oyster beds has never been attempted because of the large number of areas and lack of sufficient resources for enforcement. Some areas where enhancement activities are conducted, and shell fishing activities are restricted or prohibited, except by proclamation, are designated as shellfish management areas.

Seed oyster management areas are open harvest areas that, by reason of poor growth characteristics, predation rates, overcrowding or other factors, experience poor use of oyster populations for direct harvest and sale to licensed dealers and are designated by the Marine Fisheries Commission as a source of seed for public and private oyster culture. Seed oyster management areas are designated in Rule 15A NCAC 03R .0116 and trawl nets, long haul seines, and swipe nets are unlawful to use in designated seed oyster management areas.

Trawl Effects on Submerged Aquatic Vegetation (SAV)

For a complete review of habitat requirements, distribution, ecological role and functions, fish use, biological functions and status of SAV habitat see the North Carolina Coastal Habitat Protection Plan Source Document (NCDEQ 2016).

SAV is fish habitat dominated by one or more species of underwater vascular plants. The North Carolina Marine Fisheries Commission defines SAV habitat as submerged lands that (Rule 15A NCAC 03I .0101 (4)(i); NCDEQ 2016):

i. Are vegetated with one or more species of submerged aquatic vegetation including bushy pondweed or southern naiad (*Najas guadalupensis*), coontail (*Ceratophyllum demersum*), eelgrass (*Zostera marina*), horned pondweed (*Zannichellia palustris*), naiads (*Najas* spp.), redhead grass (*Potamogeton perfoliatus*), sago pondweed

(*Stuckenia pectinata*, formerly *Potamogeton pectinatus*), shoalgrass (*Halodule wrightii*), slender pondweed (*Potamogeton pusillus*), water stargrass (*Heteranthera dubia*), water starwort (*Callitriche heterophylla*), waterweeds (*Elodea* spp.), widgeon grass (*Ruppia maritima*) and wild celery (*Vallisneria americana*). These areas may be identified by the presence of above-ground leaves, below-ground rhizomes, or reproductive structures associated with one or more SAV species and include the sediment within these areas;

Or

ii. have been vegetated by one or more of the species identified in Sub-item (4)(i)(i) of this rule within the past 10 annual growing seasons and that meet the average physical requirements of water depth (six feet or less), average light availability (Secchi depth of one foot or more), and limited wave exposure that characterize the environment suitable for growth of SAV. The past presence of SAV may be demonstrated by aerial photography, SAV survey, map, or other documentation. An extension of the past 10 annual growing season's criteria may be considered when average environmental conditions are altered by drought, rainfall, or storm force winds.

SAV is included as fish habitat under MFC rules defined above, modified to include low salinity species and to address difficulties in identification of SAV habitat in 2009. The previous definition required the presence of leaves, shoots, or rhizomes. However, because the presence of SAV varies seasonally and inter-annually, a single inspection could result in improper habitat determination. The modified rule defines habitat to include areas where SAV is present, or areas where there is documentation of professional knowledge of its presence within the past ten growing seasons.

SAVs occur in subtidal and intertidal zones and provide refuge, forage, spawning and nursery areas for many organisms including red drum, spotted seatrout, snapper/grouper, bay scallops (*Argopecten irradians*), and penaeid shrimp. SAVs provide important ecosystem functions such as structural complexity, sediment and shoreline stabilization, primary productivity, and nutrient cycling.

There are two distinct groups of SAV ecosystems in NC distributed according to estuarine salinity. One group, referred to as low salinity SAV, thrives in fresh and low salinity riverine waters (<10 ppt). The second group, referred to as high salinity SAV or seagrass, occurs in moderate to high (>10 ppt) salinity estuarine waters of the bays, sounds, and tidal creeks. These groups are distinguished by different species composition and living requirements, and have characteristics similar to SAV communities found in many other estuaries in the U.S. While most SAV is found in water depths less than six feet, Costa (1988) noted in Buzzards Bay Massachusetts in poorly flushed areas where water transparency is poor, eelgrass was only present in shallower depths (2.0-5.9 feet) while in well flushed offshore waters eelgrass was found in deeper depths (9.8-19.7 feet). It is difficult to gauge the historic extent of SAV distribution in North Carolina because of inadequate records. However, journal accounts from fishermen describe SAV beds in coves along mainland Pamlico Sound during the 1800s where it was absent in the late 1990s (NCDEQ 2016). In addition, historic accounts have documented the presence of SAV in the upper portions of the Neuse and Pamlico rivers and in areas of Albemarle Sound.

Natural events, human activities, and climate change influence the distribution and quality of SAV habitat. Natural events include shifts in salinity due to drought and excessive rainfall, animal foraging, storm events, temperature, and disease. SAV is vulnerable to water quality degradation, in particular suspended sediment and pollutant runoff (NCDEQ 2016). The majority of SAV loss can be attributed to large-scale eutrophication (nutrient enrichment) and sedimentation, which reduces light penetration to the plants (Costello and Kenworthy 2011). It should be noted in North Carolina, even in areas where shrimp trawling is prohibited, like Albemarle Sound, Currituck Sound, upper Neuse River, upper Pamlico River, Pungo River, and most primary and secondary nursery areas (Figures 2.1.1a), SAV is either absent or limited to depths less than six feet suggesting factors other than shrimp trawling limit the extent of SAV distribution.

Bottom disturbing fishing gears can damage SAV by shearing blades, seeds and/or flowers, uprooting or burying entire areas of habitat, or increasing turbidity causing a reduction in light required for critical metabolic processes like photosynthesis. Impacts from trawling over SAV may occur from the sweep of the net or the digging of the trawl doors into the sediment (ASMFC 2000). Estimates of maximum cutting depth for otter trawl doors range from an inch to a foot (2.54-30.48 cm) when used in depths over 100 feet (30.48 m; ASMFC 2000), although such deep water does not occur in North Carolina's estuaries. Variation in cutting depth is the result of differences in gear weight, bottom hardness and towing warp to depth ratios (a measure of the force of the gear). Little information exists on the direct impact of trawling over SAV; however, impacts can be intuitively applied based on knowledge of trawl design and mechanics and the effects of trawling in other habitats.

SAV beds on the eastern side of Pamlico, Core and Back sounds are directly protected from the impacts of trawl nets via a trawl net prohibited area (Rule 15A NCAC 03R .0106) and SAV beds north of the Intracoastal Waterway (IWW) and on the western end of Bogue Sound and in New River are protected via proclamation (NCDMF 2007). Additionally, mechanical clam harvest areas (MCHA) in Core Sound and North River have been modified and the MCHA in Bogue Sound was eliminated by proclamation to avoid overlap with SAV habitat (Proclamation SF-7-2020). SAV beds are indirectly protected from trawls via designation of primary, secondary, and special secondary nursery areas.

Trawl Effects on Soft Bottom

Most bottom trawling in North Carolina occurs over soft bottom habitat. For a comprehensive review of the impact of trawling on sediment and productivity in North Carolina waters see NCDMF (1999), NCDMF (2014a), and NCDEQ (2016).

Soft bottom covers approximately 1.9 million acres, or 90% of the 2.1 million acres of estuaries and coastal rivers in North Carolina (Riggs 2001). Soft bottom is unconsolidated, unvegetated sediment that occurs in freshwater, estuarine, and marine systems. It is found in both subtidal and intertidal zones and can be characterized by geomorphology (the shape and size of the system), sediment type, water depth, hydrography, and salinity (Street et al. 2005). As with other habitats, damage from bottom-disturbing fishing gear varies with gear type and habitat complexity. Because of a lack of structure and complexity, soft bottom habitats are considered the habitat which may be most resilient to damage by bottom-disturbing gear.

Trawling in sandy and muddy areas causes resuspension of bottom sediments resulting in increased turbidity and alteration of grain sizes. Besides the resulting turbidity, grain size of the sediment as it settles back to the bottom can be altered. Tidal transport of fine-grained sediments can alter the sediment composition by increasing average grain size of the trawled bottom (NCDMF 1999). Sandy substrate located in shallow high energy areas are regularly disturbed by natural physical processes and recover quickly (Posey et al. 1996; Kaiser 1998). Deeper (greater than 40 feet), high energy areas may also experience significant sediment disturbance from storm events, wave action and currents (Posey et al. 1996; van Denderen et al. 2015; Lambert et al. 2017). These areas would be expected to recover quickly from trawling disturbances, while areas that are deep and muddy with little natural disturbances are slow to recover from physical processes or trawling disturbances (DeAlteris et al. 1999).

Multiple studies have examined the effect of trawling on sediment in estuaries (Barnette 2001). Generally, resuspension of sediment is caused by trawl doors penetrating the sediment with depth of penetration being influenced by sediment composition and type of trawl (Delapenna et al. 2006). However, the depth of penetration by any part of the gear is always greater in muddy substrate compared to sandy substrate (NCDMF 1999). In a metanalysis of global bottom trawl studies otter trawl doors (2.44 cm on average) were found to penetrate the sediment less than other trawl types including beam trawls (2.72 cm), towed scallop dredges (5.47 cm), and hydraulic dredges (16.11 cm; Hiddink et al. 2017).

In South Creek, a tributary of the Pamlico River in NC, bottom trawling increased total suspended solid (TSS) concentrations one to three times more than pre-trawl levels, with concentrations returning to pre-trawl levels by the next day (Corbett et al. 2004). Under high wind and current conditions TSS dispersed throughout the water column but redeposited relatively quickly when wind and current were low. In Hillsborough Bay, a shallow microtidal estuary on the Gulf coast of Florida, suspended sediment concentrations had similar increases from trawling and large vessel wakes with plumes persisting for eight hours and sediment transport dependent on currents and sediment type (Schoellhamer 1996). Generally, in shallow waters, like Pamlico Sound with an average depth of 16 feet, wind has been shown to cause as much resuspension of sediment as trawling (Cahoon et al. 2002: Corbett et al. 2004). Recovery from bottom trawl disturbance is dependent on sediment type, depth, currents and bioturbation (Barnette 2001).

Globally, marine sediments are an important carbon sink (Atwood et al. 2020), and shallow coastal waters, like North Carolina estuaries, can serve as carbon sinks (Crosswell et al. 2014). Under certain conditions, bottom disturbance, including bottom trawling, can re-mineralize sedimentary carbon to CO_2. At a global scale, estimates of the amount of aqueous CO_2 emissions from disturbed marine sediments are comparable to estimates of carbon loss from soil during terrestrial farming, though global estimates of CO_2 released from bottom trawling are preliminary and represent a best estimate based on available data that require further research to verify (Sala et al. 2021). Carbon stocks in marine sediments vary across depths and regions with almost four times as much carbon in deep sea sediment (>1,000 meters; >3,281 feet) than in shallow seas (Atwood et al. 2020), though this largely due to the extreme difference in total area. While generally functioning as carbon sinks, shallow estuarine areas, like Pamlico Sound, can also become carbon sources during periods of high winds (Crosswell et al. 2014). The extent to which disturbance from bottom trawling releases carbon from sediments in Pamlico Sound compared to carbon released from natural events is unknown and requires further work.

Bottom disturbance can also resuspend pollutants like heavy metals, polycyclic hydrocarbons (PAHs), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), and pesticides bound to sediment particles. Toxins can affect benthic invertebrates by inhibiting or altering reproduction or growth, and in some cases causing mortality (Weis and Weis 1989). Because low concentrations of heavy metals in the water column can be easily incorporated into fine grained sediment, particularly organic rich muds which is a common bottom type in North Carolina estuaries, chemicals can accumulate in the sediment to toxic levels and be resuspended into the water column (Riggs et al. 1991). In Hancock and Slocum creeks, Corbett et al. (2009) found higher rates of sedimentation and contamination in sediment than in the higher energy Neuse River mainstem. Resuspension of sediments where heavy metals and other contaminants are found could have serious consequences with more significant effects where contaminants are found in higher concentrations (i.e., near areas affected by major industrialization; Barnette 2001), though the extent to which contaminants may be resuspended by natural processes compared bottom disturbance by trawls is unknown.

General Impacts of Trawling

For a comprehensive review of the impact of trawling on sediment and productivity in North Carolina waters, see NCDMF (1999), NCDMF (2014a), and NCDEQ (2016).

The effects of trawling on benthic habitat have been well documented (NCDMF 1999; Barnette 2001; NCDEQ 2016; Hiddink et al. 2017; Sciberras et al. 2018). Impacts from mobile bottom-disturbing fishing gear, like shrimp trawls, range from changes in community composition from removal of species to physical disruption of the habitat (Barnette 2001).

Bottom trawling is generally more damaging when occurring over structurally complex biotic habitat like oyster reefs, or SAV (Althaus et al. 2009; Cook et al. 2013) when compared to effects on sandy shallow soft bottom that is lacking structure but can also be damaging to these habitats depending on composition of sediment and type of trawl (Brown 1989; Engel and Kvitek 1998; Collie et al. 2000; Hiddink et al. 2017; Sciberras et al. 2018). However, in many areas, including deep sea habitats, bottom disturbance from natural processes is similar to bottom disturbance from trawls depending on many factors including depth and sediment type (Diesing et al. 2013; van Denderen et al. 2015; Lambert et al. 2017). In areas of high natural disturbance, the benthic community is more resilient to bottom trawl impacts and recovers quickly from disturbance (van Denderen et al. 2015). Bottom trawling can reduce small scale habitat complexity (Auster and Langton 1999) and reduce epifauna abundance and diversity (Kaiser and Spencer 1996; Hinz et al. 2008). Primary productivity can be reduced due to increased turbidity, disruption of the benthic microalgae, and secondary effects on the food chain (West et al. 1994). Increased turbidity reduces light penetration and consequently, the primary productivity of benthic microflora on the seafloor, as well as phytoplankton in the water column (Auster and Langton 1999). The sediment composition of the bottom can also change with frequent trawling. Given the close relationship between sediment size and benthic community structure, this sediment shift will alter the benthic community (Thrush and Dayton 2002).

Shrimp trawling can reduce or degrade structure and habitat complexity by disturbing epifauna, smoothing bedforms, and removing organisms but the magnitude of trawling disturbance is highly variable depending on habitat type, gear type, intensity, and duration of trawling and natural disturbances (Barnette 2001).

Critical Habitat Areas

The 1996 amendment to the federal Magnuson-Stevens Act recognized the loss of marine and estuarine habitat as a long-term threat to the viability of U.S. fisheries and emphasized habitat conservation as an important component of fisheries conservation and management. The amendment defined essential fish habitat (EFH) as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." (Magnuson-Stevens Act 16 U.S.C. 1802 §3(10)) and designated habitat areas of particular concern (HAPC) as a subset of EFH. Designations do not confer any specific habitat protections but can focus habitat conservation efforts. The federal councils have taken a range of approaches to designating HAPCs. The South Atlantic Fishery Management Council (SAFMC) designates specific habitat types (i.e., submerged aquatic vegetation) and discrete sites with known boundaries (e.g., the “Point” and “Ten Fathom Ledge”) as HAPCs while the Gulf and Caribbean Councils designate discrete areas (MAFMC 2016). The Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC) use the more general and broad application of the HAPC terminology by designating habitat types and not discrete sites. The National Marine Fisheries Service (NMFS) has encouraged the councils to shift HAPC designations from broad habitat types to discrete, geographically defined sites for more effective management (SAFMC 2016).

Shallow habitats with structure, such as SAV and oyster reefs, provide more predator protection and food than soft bottom habitat, enhancing growth and survival of juvenile fish (Lehnert and Allen 2002; Ross 2003; Grabowski et al. 2005). Multiple studies have documented that abundance of penaeid shrimp, sciaenids (fish in the drum family including Atlantic croaker, spot, red drum, spotted seatrout, etc.), and other estuarine dependent species is significantly greater in SAV, and oyster reef habitat than in soft bottom habitat (NCDEQ 2016). Shell bottom is widely recognized as EFH for oysters and other reef-forming mollusks (ASMFC 2007). In addition to its role as EFH for oysters, shell bottom provides critical fisheries habitat for ecologically and economically important finfish, mollusks, and crustaceans. The SAFMC considers shell bottom to be EFH for black drum (*Pogonias cromis*), striped bass (*Morone saxatilis*), weakfish, spotted seatrout, summer flounder (*P. dentatus*), and southern flounder and SAV is considered EFH for shrimp, red drum, snapper and grouper species, and spiny lobster (*Palinuridae* spp.).

IV. AUTHORITY

<u>North Carolina General Statutes</u>
§ 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

North Carolina Marine Fisheries Commission Rules
15A NCAC 03H .0103 Proclamations, General
15A NCAC 03J .0104 Trawl Nets
15A NCAC 03K .0103 Shellfish Management Areas
15A NCAC 03K .0208 Seed Oyster Management Areas
15A NCAC 03K .0209 Oyster Sanctuaries
15A NCAC 03L .0101 Shrimp Harvest Restrictions
15A NCAC 03L .0103 Prohibited Nets, Mesh Lengths and Areas

V. DISCUSSION

- Section focuses on habitat protections in areas from Core Sound and South
- Management options in *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas* and *Appendix 2.3: Reducing Shrimp Trawl Bycatch Through Area Closures that Increase Connectivity Between Closed Areas* may also provide additional habitat protections and should be considered in conjunction with this issue paper
- Goal of this paper is protecting SAV and shell bottom habitat from damage by shrimp trawls

The focus of this issue paper is areas from Core Sound and South because of the higher frequency of critical shell bottom and SAV habitat. However, depending on the management approach taken in the *Shrimp Management in Special Secondary Nursery Areas* and *Reducing Shrimp Trawl Bycatch Through Area Closures that Increase Connectivity Between Closed Areas* issue papers additional critical habitat protections in other areas may need to be considered. Examples of where and how those protections could occur are discussed in this paper.

There are approximately 2.2 million acres of coastal estuarine waters (excluding the ocean) in North Carolina, of which 242,642 acres are joint waters. The NCMFC has designated 161,830 acres as either Primary Nursery Areas (PNAs), Permanent Secondary Nursery Areas (SNAs), or Special Secondary Nursery Areas (SSNAs), which represent 7% of the total estuarine waters (Table 2.1.1, Appendix 3 Maps 3.1-3.12). Additionally, the North Carolina Wildlife Resources Commission (NCWRC) has designated 30,384 acres of inland waters under its jurisdiction as inland nursery areas. PNAs and SNAs are permanently closed to certain fishing gears, while SSNAs are conditionally opened to certain fishing gears (see *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas*).

In the 1980s, the NCDMF formed an internal Critical Habitat Committee to work with the North Carolina Marine Fisheries Commission (NCMFC) Habitat Advisory Committee to discuss the concept of expanding habitat protections. The committee recommended expanding fish sampling to identify anadromous spawning and nursery areas, estuarine areas important to juvenile reef fish like gag grouper (*Mycteroperca microlepis*), black sea bass (*Centropristis striata*), and sheepshead (*Archosargus probatocephalus*), and mapping of shellfish and SAV resources due to their importance as nursery area (Noble and Monroe 1991). The Estuarine Benthic Mapping Program was implemented in 1990 and Critical habitat definitions were put into rule in 1994 (15A NCAC 03I .0101 (4)).

The Coastal Habitat Protection Plan (CHPP) initiated a process to identify strategic habitat areas (SHAs) for key species (NCDEQ 2016). The CHPP recommended identification, nomination, and designation of SHAs as a tool to focus habitat and water quality protection efforts. However, before SHAs can influence regulatory management strategies, sampling of indicators is needed to verify ecosystem function and identify site-specific management needs (NCDEQ 2016). While the SHA verification process is underway, it may be years before statewide verification of SHA nominations are complete. Because the historic extent of SAV habitat since 1981 and known shell bottom areas have been mapped (Figure 2.1.1a-g), additional habitat protections should be considered prior to SHA verification.

Specific critical habitat protections, including protections for SAV and shell bottom have been implemented as part of Fishery Management Plans for shrimp (NCDMF 2006; 2015), oysters (NCDMF 2001), bay scallop (NCDMF 2007), and blue crab (NCDMF 1998; 2020). In addition, the 2006 Shrimp Fishery Management Plan included consideration of a strategy to expand areas where dredging and trawling is prohibited to allow some recovery of SAV and shell bottom where those habitats historically occurred (NCDMF 2006). Trawling and dredging is prohibited in SAV beds on the eastern side of Pamlico, Core and Back sounds through a no trawl area designation (Rule 15A NCAC 03R .0106). SAV beds north of the Intracoastal Waterway (IWW) and on the western end of Bogue Sound are protected via proclamation (NCDMF 2007). SAVs in New River are also protected within no trawl areas. Trawling was prohibited in Albemarle and Currituck sounds due to user conflicts, but the prohibition also provided ancillary protections for habitat (Rule 15A NCAC 03J .0104). Trawl nets, long haul seines, and swipe nets are prohibited in any designated oyster sanctuary (355.80 acres); shellfish (25.57 acres) or seed management areas (2,590.26 acres; Rule 15A NCAC 03K .0103). Crab spawning sanctuaries (Rule 15A NCAC 03L .0205) and inlet trawling restrictions (Rule 15A NCAC 03J .0401) provide a “no trawl corridor” around inlets that protect crabs and allows migration of sub-adult fish to the ocean.

The NCDMF Director, through proclamation authority, may designate cultch planting sites as shellfish management areas thereby protecting them from bottom disturbing gears. Currently, 2,971.63 acres have been designated as oyster sanctuary, shellfish or seed management areas which are required, by rule, to be marked with signs or buoys (Table 2.1.2; Figure 2.1.1a-g). While cultch planting has occurred at thousands of sites throughout the state, very few have been designated as shellfish management areas primarily because they have been managed as open harvest areas. In addition, marking sites can be difficult and prior to 2002, cultch planting locations are uncertain because of Loran to GPS coordinate conversion errors (J. Peters, NCDMF, personal communication). When adequately marked, smaller trawlers will usually avoid cultch planting sites due to the damage cultch material causes to nets. Public meetings are held prior to the annual cultch planting season to solicit input from the public on locations for cultch planting sites. While input from shrimp trawlers would be useful in reducing impact of cultch locations to the shrimp trawl fishery, the meetings are generally poorly attended with minimal input on locations and no feedback from shrimp trawlers (C. Luck and C. Stewart, NCDMF, personal communication). Generally, there seems to be little overlap or conflict between cultch planting locations and the shrimp trawl fishery because cultch planting sites are in shallow water where minimal shrimp trawling occurs. Cultch material has been planted on 634.44 acres in North Carolina’s estuarine waters, of which, 64.4% (408.36 acres) occurs in areas already closed to trawling.

Beds of SAV occur in North Carolina in subtidal, and occasionally intertidal, areas of sheltered estuarine and riverine waters where there is suitable sediment, adequate light reaching the bottom, and moderate to negligible current velocities of turbulence (Ferguson and Wood 1994; Thayer et al. 1984). SAV habitat is primarily located in shallow water (< 6 feet) where minimal trawling occurs. Of the 191,155 acres of historical SAV distribution in North Carolina's estuarine waters, 77.2% (222,769.68 acres) occurs in areas closed to shrimp trawling (Figure 2.1.1a-g).

Because most SAV and shell bottom habitat occurs in shallow water one method for protecting these habitats could be to prohibit trawling within certain depth contours. A similar strategy is used to define designated pot areas where shrimp trawling is prohibited in the Pamlico, Bay and Neuse rivers from June 1 to November 30 in less than six feet of water. Prohibiting shrimp trawling in less than six feet of water, or in less than 12 feet of water in specific areas or statewide would provide protection for a majority, or all shell bottom and SAV habitat. However, this type of restriction is difficult to enforce and could be difficult to comply with depending on the capability of individual shrimp trawl boats. Depending on the depth contour used, areas where critical habitat does not occur might be closed to shrimp trawling which could be detrimental to the shrimp trawl fishery.

Additional protections for some or all SAV and shell bottom habitat occurring outside of currently closed areas should be considered and may be necessary as SAV and shell bottom habitat naturally expands, or new cultch planting locations are added. The management framework by which shrimp trawling can be restricted in SAV and shell bottom habitats already exists. Existing no shrimp trawl areas could be expanded, or new no shrimp trawl areas could be designated to create more extensive areas of habitat protection. No shrimp trawl areas are used to protect SAV habitat in New River, Bogue, eastern Pamlico, and Core sounds and these areas could be expanded to encompass additional SAV habitat. Including cultch planting locations in no shrimp trawl areas would eliminate the need to designate and mark individual sites as shellfish management areas and creating more clearly identified no shrimp trawl lines may be more effective than marking several smaller areas individually.

In the New River, shrimp trawl areas occur in the same area as the MCHA, which were adjusted to protect SAV in 2017 (Figure 2.1.2). Additionally, MCHAs in Core Sound and North River have been modified and the MCHA in Bogue Sound was eliminated by proclamation to avoid overlap with SAV habitat (Proclamation SF-7-2020). Where possible, in areas south of Pamlico Sound, allowing shrimp trawling to only occur within MCHAs would accomplish the objective of protecting SAV habitat and create common boundaries for enforcement. Applying this strategy in Core Sound (Figure 2.1.3) and North River (Figure 2.1.4) would provide protection for SAV habitat in these waterbodies, streamline enforcement, and minimally impact shrimp trawling because most of the closed area would be locations that are not trawled because of shallow water or other obstructions. Adjacent to Core Sound, consideration could also be given to allowing shrimp trawling to continue in the marked navigable channel in the Straits area (Figure 2.1.5). This channel is an area where shrimp trawling occurs and SAV is not present.

Historic SAV mapping indicates the presence of SAV habitat near the southern shore of Bogue Sound, though SAV may not be present in these locations every year (Figure 2.1.6). While this area is open to shrimp trawling, shallow water, and the presence of SAV minimizes effort in this area, though some shrimp trawling occurs in the IWW and deeper water areas near Salter Path. The MCHA in Bogue Sound was eliminated in 2020 (Proclamation SF-7-2020) so matching the shrimp trawl area with the MCHA is not possible. Because of the patchy distribution of SAV south of the IWW in Bogue Sound, a no shrimp trawl area would need to be large enough to encompass the entire SAV area. Bogue Sound could be closed to shrimp trawling except for in the IWW and within 100 yards on the south side of the IWW and in Banks Channel from Wood Island to around Dog Island. The IWW and Banks Channel represent areas where shrimp trawling currently occurs where no SAV is present so this option would protect SAV habitat while continuing to allow shrimp trawling (Figure 2.1.7).

MCHA's are designated in Newport River, and White Oak River and shrimp trawling does occur in these rivers, though effort is generally low. However, SAV is less extensive in these waterbodies (Figure 2.1.1e-f) and likely does not require additional shrimp trawl protections. Most shrimp trawling in Newport River occurs along the Penn Point shrimp line which protects shell bottom habitat, leases, and cultch planting sites above the line. Shrimp trawling also occurs around Core Creek. Similarly, the MCHA in White Oak River does not encompass the extent of trawlable area in the river which occurs around Cahoon's slough, the Turnstake, Hills Bay, and the mouth of Pettiford Creek.

In locations with no MCHA, shrimp trawl lines could be adjusted to encompass additional SAV and shell bottom habitat. Because current understanding of SAV distribution is based on historic mapping efforts (1981-2015), maps may not represent the actual extent of SAV in any given year but does represent potential SAV habitat. Therefore, any shrimp trawl closures implemented to protect SAV must be broad enough to capture potential SAV habitat distribution and could limit the use of shrimp trawls in potentially productive areas with no SAV present. However, shrimp trawl closures that are broader provide buffer between open areas and SAV and should be considered when delineating closure areas. Shrimp trawl closures to protect shell bottom habitat, particularly cultch planting areas, could be implemented to protect these areas from damage by shrimp trawls. In addition, defining areas of shell bottom as no shrimp trawl areas may prevent damage to shrimp trawl gear. However, since oyster dredges are allowed in cultch planting areas in the north, the ecological benefit of restricting shrimp trawls in these areas would be limited.

Modification of no shrimp trawl lines could be accomplished via revision of existing proclamations or suspending rules via proclamation. This method of implementation may be most effective in locations where no trawl areas already exist and are near SAV and shell bottom habitat. Creating no shrimp trawl areas around SAV and shell bottom habitat would be effective in areas where existing closures do not exist or where modification of existing no shrimp trawl areas is not realistic. For example, West Bay is closed to trawling early in the season but can be opened to shrimp trawling (Figure 2.1.8). There are no existing no shrimp trawl areas near West Bay, so creating a no shrimp trawl area in West Bay encompassing SAV and shell bottom habitat would define an area as open to trawling (Figure 2.1.9). For either implementation method, creating lines that use existing landmarks and are clear would be important for promoting compliance and simplifying enforcement. Another option would be to prohibit shrimp trawling within a certain depth contour within West Bay that would encompass critical habitat areas. Similar options could be considered in Croatan and Roanoke sounds where critical habitats are present but no specific management options were discussed in this issue paper. Management options in *Appendix 2.2:*

Shrimp Management in Special Secondary Nursery Areas and *Appendix 2.3: Reducing Shrimp Trawl Bycatch Through Area Closures that Increase Connectivity Between Closed Areas* may also provide additional habitat protections and should be considered in conjunction with this issue paper.

The management options discussed in this issue paper represent immediate, direct action that can be taken through review of the shrimp FMP to protect critical shell bottom and SAV habitat. Direct protections of SAV and shell bottom habitat aligns with the strategy from the 2006 Shrimp FMP to expand areas where dredging and trawling is prohibited to allow some recovery of SAV and shell bottom where those habitats historically occurred (NCDMF 2006) and the priority that has been put on SAV in the current CHPP review. A long-term, more effective strategy to protect critical habitat, including SAV and shell bottom, is needed to focus future protections in areas designated as SHAs. SHA nominations have been completed for areas throughout the state (NCDMF 2009; 2011; 2014; 2018), but cannot influence regulatory management strategies until designation, based on verification of ecosystem function and identification of site-specific management needs (NCDEQ 2016). SHAs identified in the CHPP represent a subset of priority habitat areas for protection due to their exceptional condition or imminent threat to their ecological functions supporting finfish and shellfish species (Deaton et al. 2006). The SHAs have been nominated on scientific understanding of relationships between habitats, connectivity, and fish production. Because of the rigorous scientific process in which SHAs are identified and designated, additional habitat protections or modification of existing habitat protections should be considered upon completion of SHA designations.

While closing areas of critical SAV and shell bottom habitat allows for calculation of how much additional habitat will be protected, additional benefits are difficult to quantify because physical disturbance by shrimp trawls is not the primary threat to these habitats, particularly SAV. In the absence of shrimp trawls, shell bottom habitat may still be covered by sediment and SAV growth may be impaired by poor water quality, climate change, disease or other natural disturbances.

VI. PROPOSED RULE(S)

This action will result in no immediate rulemaking, rather existing proclamation authority pertaining to use of trawls may be used.

VII. MANAGEMENT OPTIONS AND IMPACTS

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

1. *Status Quo* – Maintain the areas open to shrimp trawling as identified in current rules and proclamation.
   + Continued access to resources by shrimpers
   + Will not create shifts in effort to other areas
   + Area closures to address bycatch considered in Amendment II may provide additional habitat protections

+ Most cultch planting areas are open to oyster harvest so prohibiting shrimp trawling has limited ecological benefit
+ Most SAV and shell bottom habitat already occurs in areas closed to shrimp trawling
- SAV and shell bottom habitat may be damaged by continued trawling
- Could have negative impacts on important fish stocks
- Could negatively affect historic and future cultch planting efforts
- Lack of clear boundaries could lead to damages to trawl gear

2. Modify existing or create new shrimp trawl closure lines to protect additional SAV habitat.
   + Decrease damage to SAV from shrimp trawls
   + Minimal impact to fishermen since areas are not used extensively
   + Modification of closure lines would occur by proclamation allowing for flexibility
   + Identifying clear boundaries could prevent damage to gear and habitat
   + Bycatch reduction
   - May decrease some traditional shrimp trawling areas
   - Could shift effort to other areas
   - SAV mapping reflects historic distribution, so creation of broad no shrimp trawl areas may prevent shrimp trawling in productive areas with no SAV
   - Modification of existing closure lines could cause confusion

3. Modify existing or create new shrimp trawl closure lines to protect additional shell bottom habitat.
   + Decrease damage to shell bottom habitat from shrimp trawls
   + Minimal impact to fishermen since areas are not used extensively
   + Closure lines would occur by proclamation allowing for flexibility
   + Identifying clear boundaries could prevent damage to gear and habitat
   + Bycatch reduction
   - May decrease some traditional shrimp trawling areas
   - Could shift effort to other areas
   - Shellfish management areas are already closed to trawling
   - Most cultch planting areas are open to mechanical oyster harvest so prohibiting shrimp trawling has limited ecological benefit
   - Modification of existing closure lines could cause confusion

VIII. SHRIMP FMP WORKSHOPS

Shrimp FMP Workshops were held in March 2021 between the division plan development team and the Shrimp FMP Advisory Committee (AC). The goal of these workshops is for the AC to assist the division in drafting the plan. The division presented discussion points to guide conversation and inform specific areas where stakeholder input was needed in addition to other AC feedback. The guidance received during workshops on the protection of critical shell bottom and SAV habitat was incorporated into the draft plan. Overall, AC members expressed supported protections of critical shell bottom and SAV habitat through area closures. The commercial AC members suggested additional areas that could be left open to shrimp trawling that do not overlap with existing SAV habitat adjacent to Core Sound and in Bogue Sound. Other AC members suggested building in closed area buffers between open shrimp trawl areas and existing shell bottom and SAV habitat but largely deferred to commercial AC members for recommendations of specific area closures.

IX. RECOMMENDATION

The division will make recommendations after receiving input from the public and the MFC Advisory Committees.

X. LITERATURE CITED

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Tables

Table 2.1.1. Existing areas closed to the use of trawls in coastal and estuarine waters of North Carolina.

Type of Closure	Location	Restriction	Purpose	Reference
Primary Nursery Area	Statewide/Internal Coastal Waters	Unlawful to use trawl nets or other bottom disturbing gear	Protect habitat for juvenile fish and shrimp	15A NCAC 03N .0104 15A NCAC 03R .0103
Secondary Nursery Area	Statewide/Internal Coastal Waters	Unlawful to use trawl nets	Protect habitat for juvenile fish and shrimp	15A NCAC 03N .0105(a) 15A NCAC 03R .0104
Special Secondary Nursery Area	Statewide/Internal Coastal Waters	Can be opened to the use of trawl nets by proclamation from August 16 to May 14	Protect habitat for juvenile fish and shrimp while allowing taking of shrimp after they have grown or when juvenile fish have left area	15A NCAC 03N .0105 15A NCAC 03R .0105
Trawl Net Prohibited Areas	Statewide/Coastal and Internal Coastal Waters	Unlawful to use trawl nets; parts of Pamlico, Core and Back sounds can be opened to peeler crab trawling by proclamation	Protect sensitive habitat or reduce bycatch	15A NCAC 03J .0104(b)(3)(4) 15A NCAC 03R .0106
Military Danger Zones	Statewide/Coastal and Internal Coastal Waters	No public access	Public safety	15A NCAC 03R .0102
Crab Spawning Sanctuaries	All coastal inlets	From Barden Inlet north unlawful to use trawls in spawning sanctuaries from March 1 to August 31; From Beaufort inlet south unlawful to use trawls in spawning	Provide protection for spawning blue crabs	15A NCAC 03L .0205 15A NCAC 03R .0110 Proclamation M-7-2020

Type of Closure	Location	Restriction	Purpose	Reference
		sanctuaries from March 1 to October 31		
Designated Pot Areas	Pamlico, Bay, Neuse rivers and their tributaries	Unlawful to use trawl nets in designated pot areas from June 1 to November 30	Reduce gear conflicts between trawls and crab pots	NCAC 03J .0104(b)(6) 15A NCAC 03J .0301(a)(2) 15A NCAC 03R .0107 Proclamation (i.e., SH-1-2020)
Seed Oyster Management Areas	Statewide/Internal Coastal Waters	Unlawful to use trawl nets in seed oyster management areas	Protect oyster habitat	15A NCAC 03K .0208 15A NCAC 03R .0116
Oyster Sanctuaries	Croatan Sound, Pamlico Sound, Neuse River	Unlawful to use trawl nets in oyster sanctuaries	Protect oyster habitat	15A NCAC 03k .0209 15A NCAC 03R .0117
Shrimp Trawl Prohibited Areas	Pungo, Pamlico, Neuse, Shallotte, Calabash rivers; Eastern Channel; Sunset Beach	Unlawful to use shrimp trawls	Protect habitat, reduce bycatch, reduce gear conflicts	15A NCAC 03L .0103(e) 15A NCAC 03R .0114
Other Trawl Closures				
Miscellaneous	Atlantic Ocean	Unlawful to use trawls in specified areas during specified times	Protect habitat, reduce bycatch, reduce gear conflicts	15A NCAC 03J .0202 (1)(2) 15A NCAC 03J .0202 (8)
Miscellaneous	Albemarle Sound and Tributaries	Unlawful to use trawls	Protect habitat, reduce bycatch, reduce gear conflicts	15A NCAC 03J .0104 (b) (3)
Miscellaneous	Southport Boat Harbor	Unlawful to use any commercial fishing gear	Reduce user group conflict, public safety	15A NCAC 03J .0206
Miscellaneous	Duke Energy Progress Brunswick Nuclear Plant Intake Canal Closure	Unlawful to use any commercial fishing gear	Public safety	15A NCAC 03J .0207

Type of Closure	Location	Restriction	Purpose	Reference
Miscellaneous	Dare County	Unlawful to use commercial fishing gear within 750 feet of licensed fishing piers when open to the public	Reduce user group conflict	15A NCAC 03J .0402(a)(1)(ii)
Miscellaneous	Onslow and Pender counties	Unlawful to use commercial fishing gear during specified times and distances from fishing piers	Reduce user group conflict	15A NCAC 03J .0402(a)(2)(A)(B)(i)(ii)
Miscellaneous	New Hanover County	Unlawful to use commercial fishing gear during specified times and distances from fishing piers	Reduce user group conflict	15A NCAC 03J 0402(a)(3)(A)(B)(i)(iii)

Table 2.1.2. Total acreage of shellfish management areas, oyster sanctuary, designated seed oyster management area, cultch planting sites and SAV habitat (1981-2015) and total acreage of estuarine waters closed to trawling.

Designation	Total Acreage
Shellfish Management Area*	26
Oyster Sanctuary*	395
Designated Seed Oyster Management Area*	2,590
SAV	191,155
Cultch Planting Sites[+]	634
Closed Estuarine Waters	1,003,634

* Closed to trawling
[+] Estimated acreage

Figures

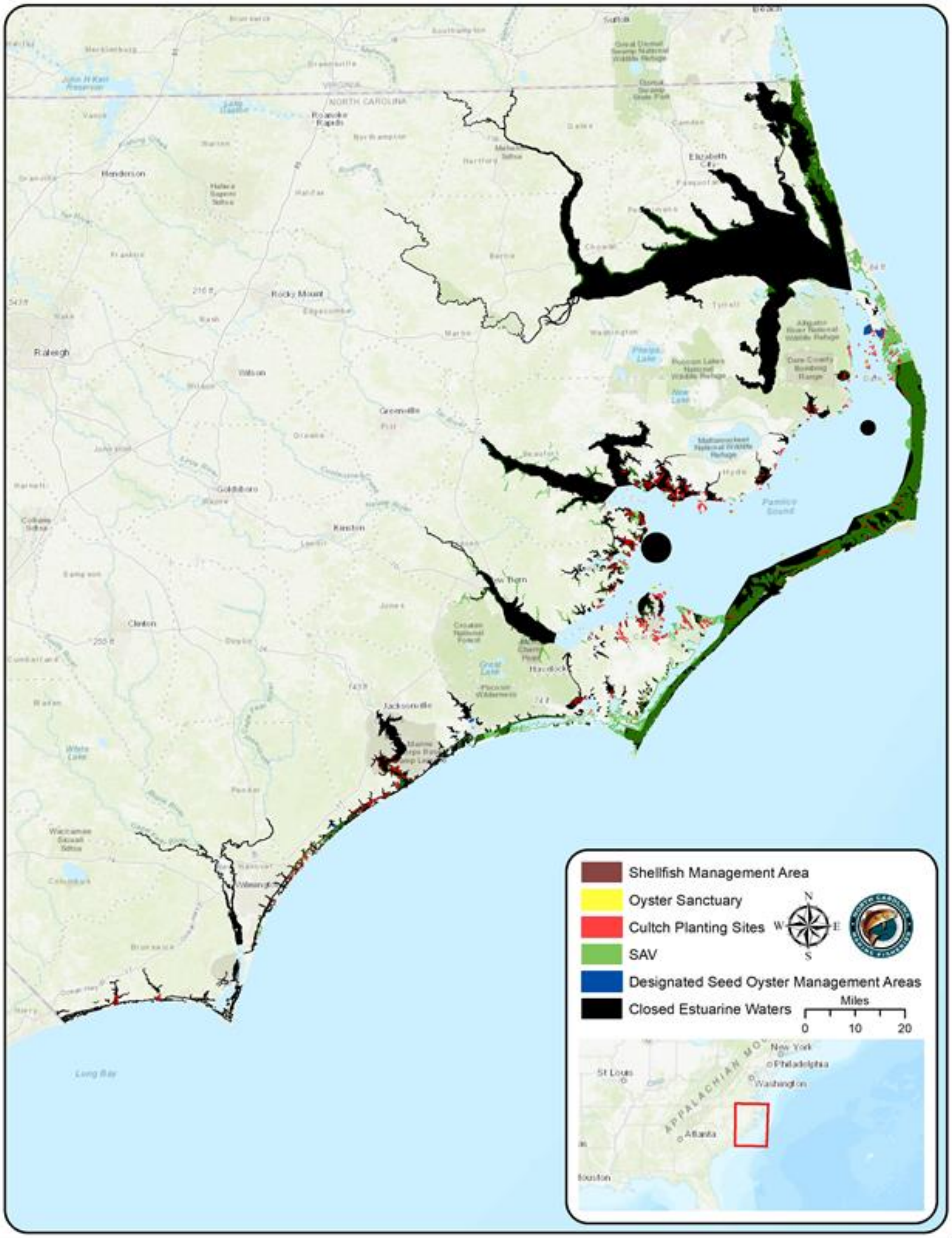

Figure 2.1.1a. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in North Carolina Estuarine waters.

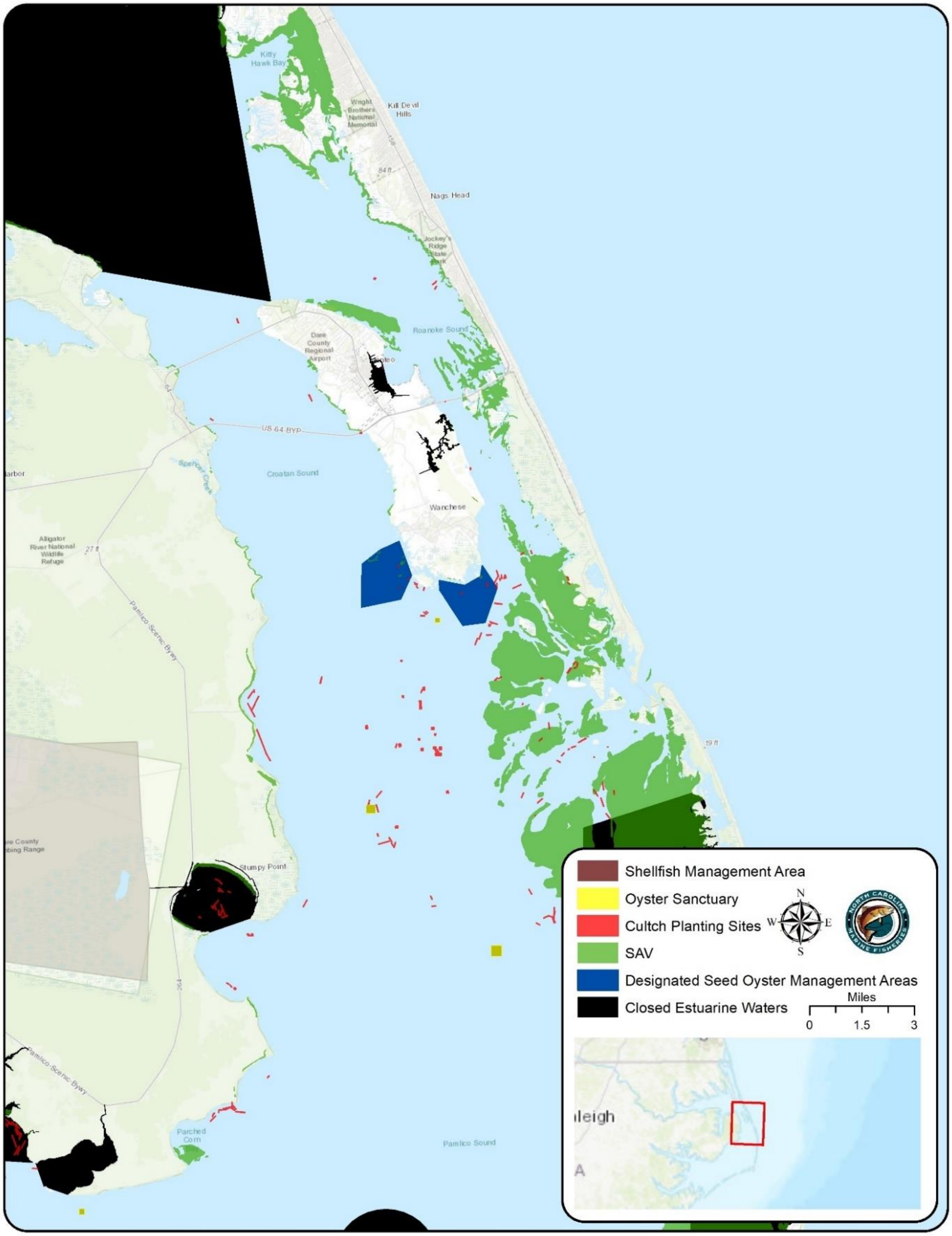

Figure 2.1.1b. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in Croatan and Roanoke sounds.

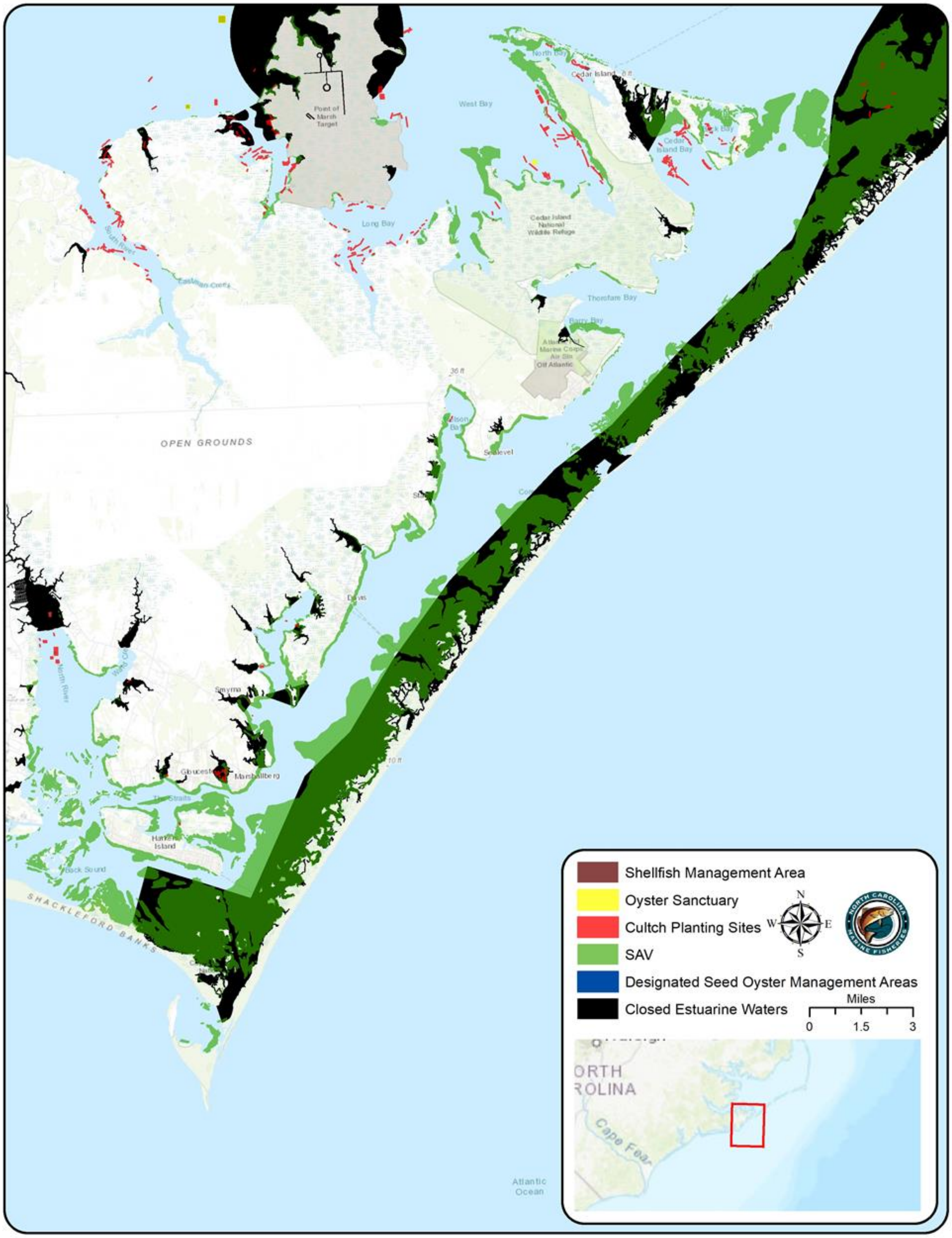

Figure 2.1.1c. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in Core Sound.

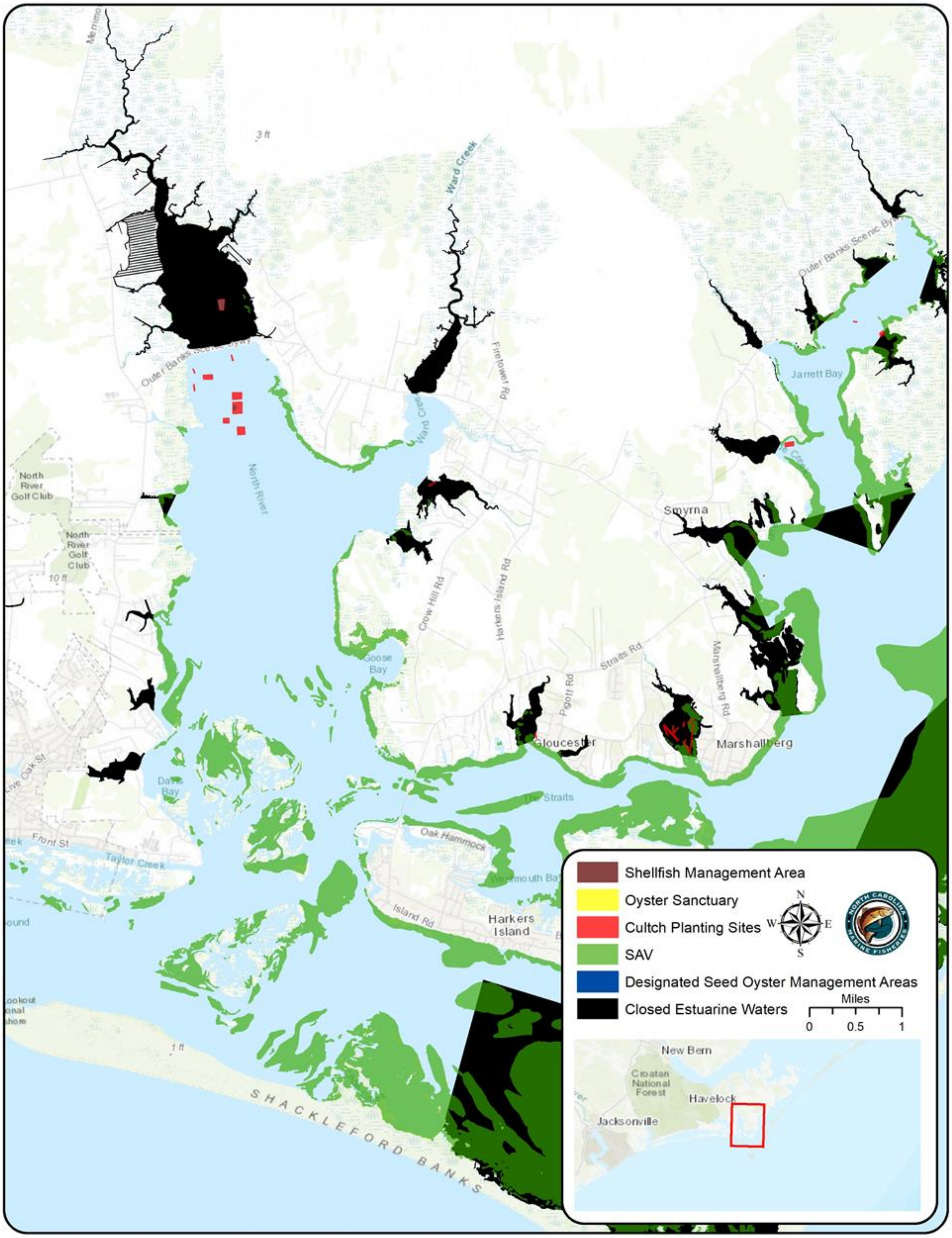

Figure 2.1.1d. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in North River.

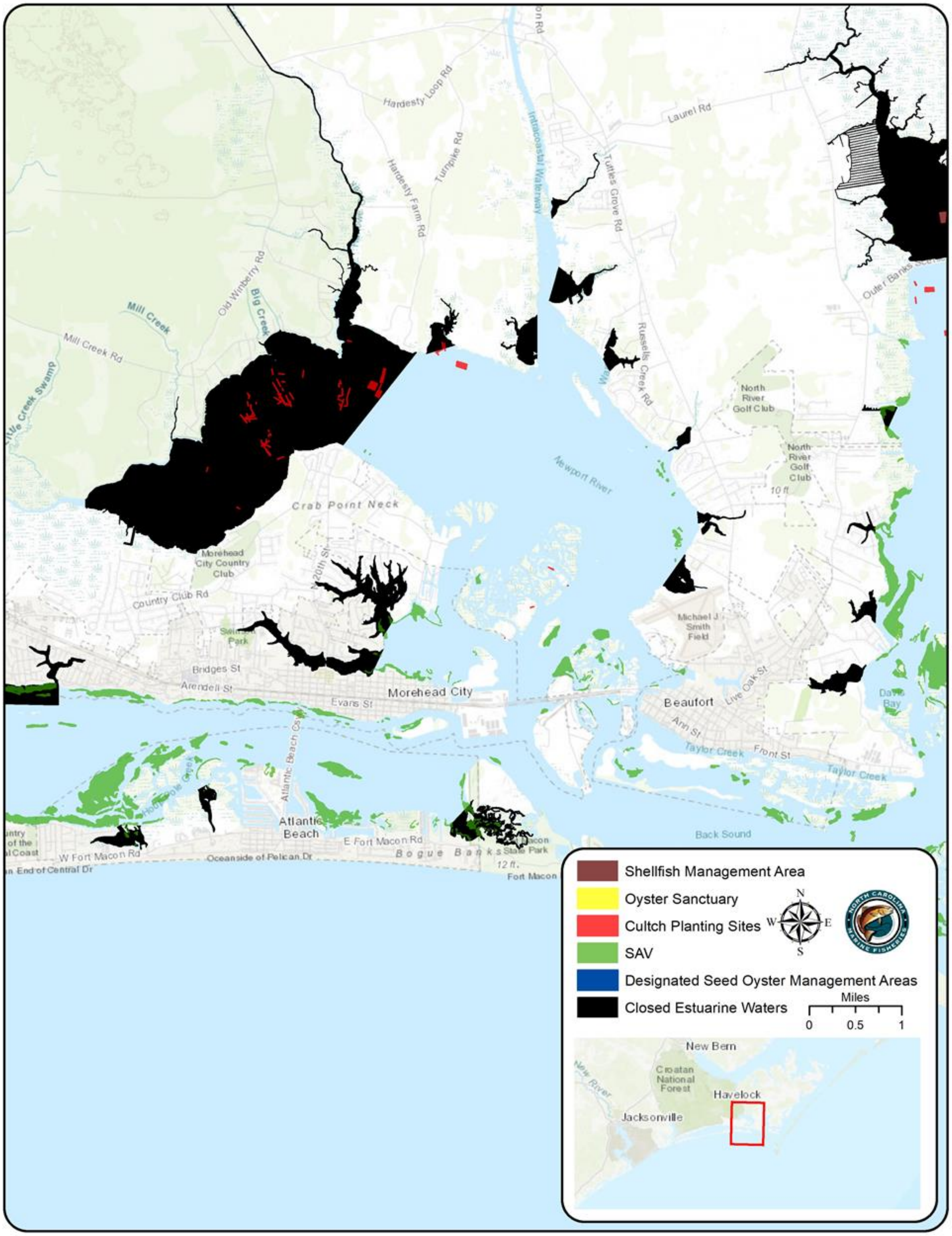

Figure 2.1.1e. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in Newport River.

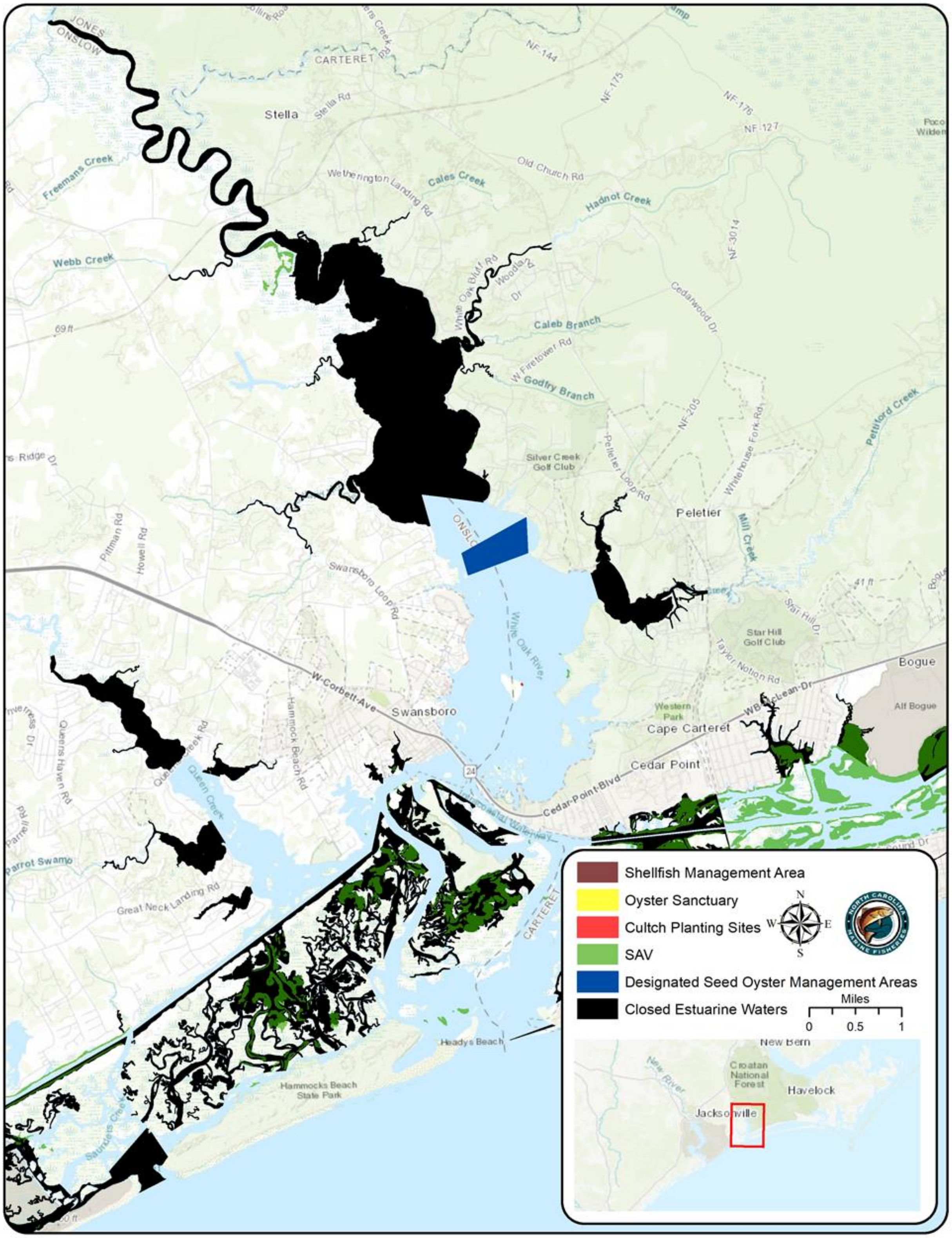

Figure 2.1.1f. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in White Oak River.

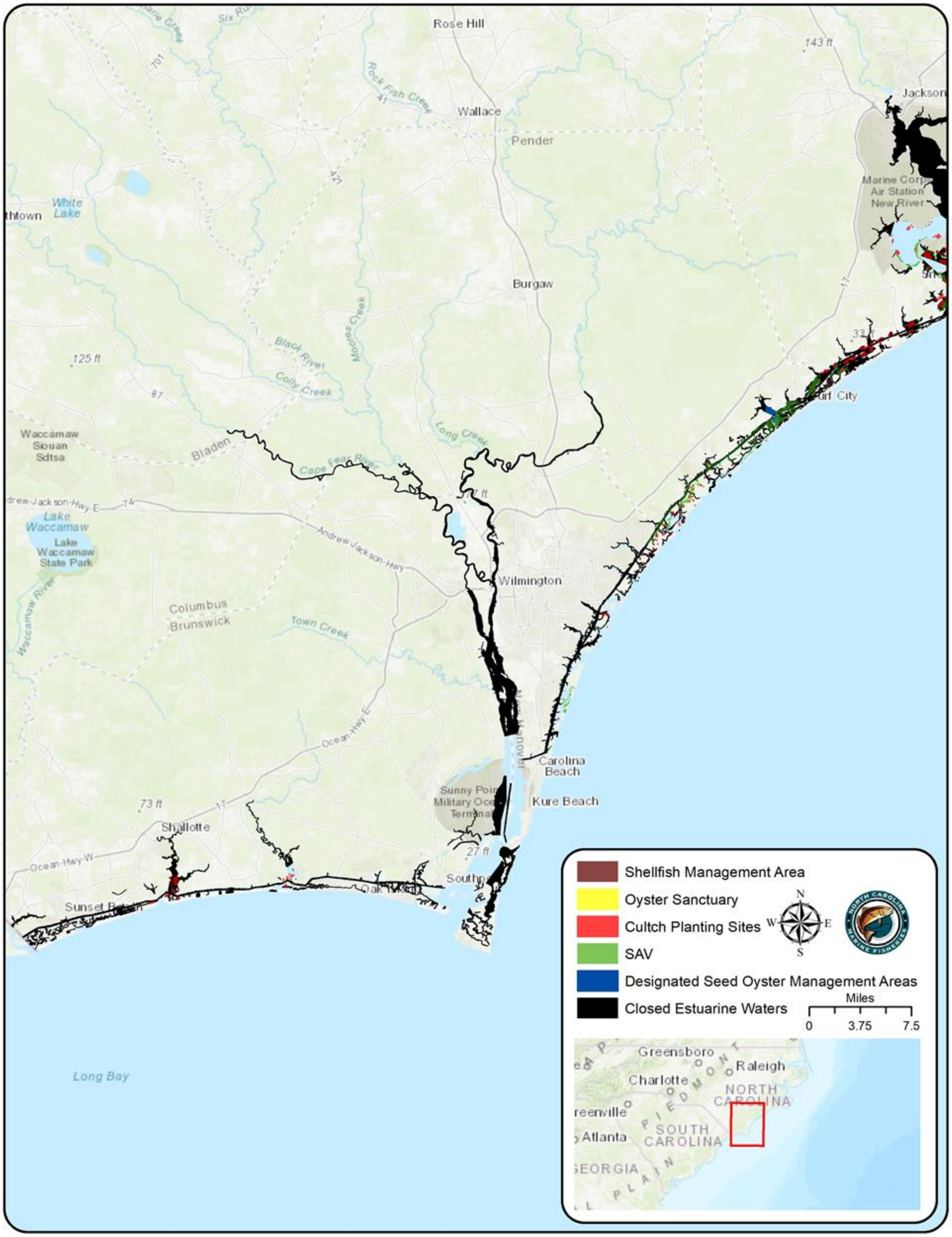

Figure 2.1.1g. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations south of New River.

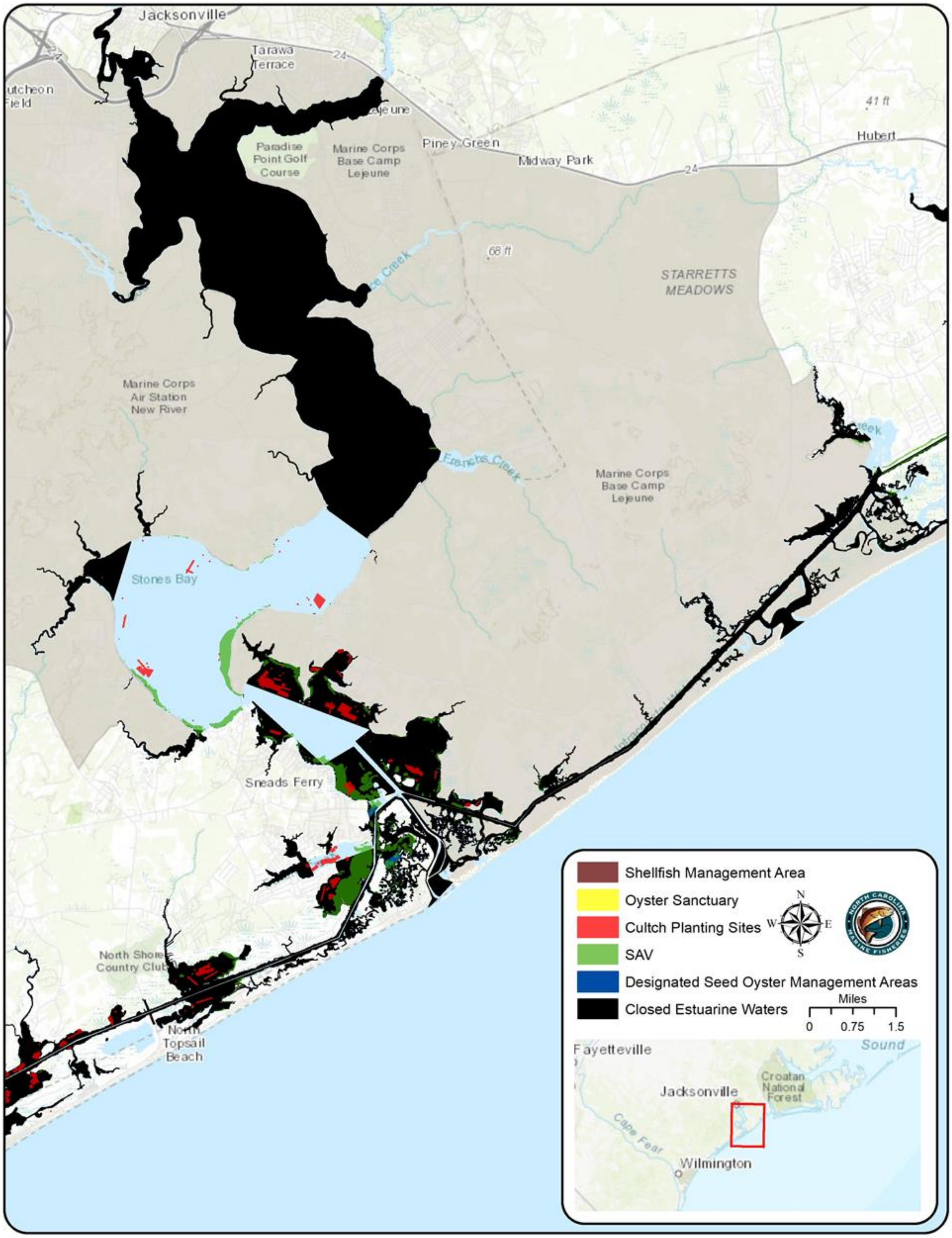

Figure 2.1.2. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in New River.

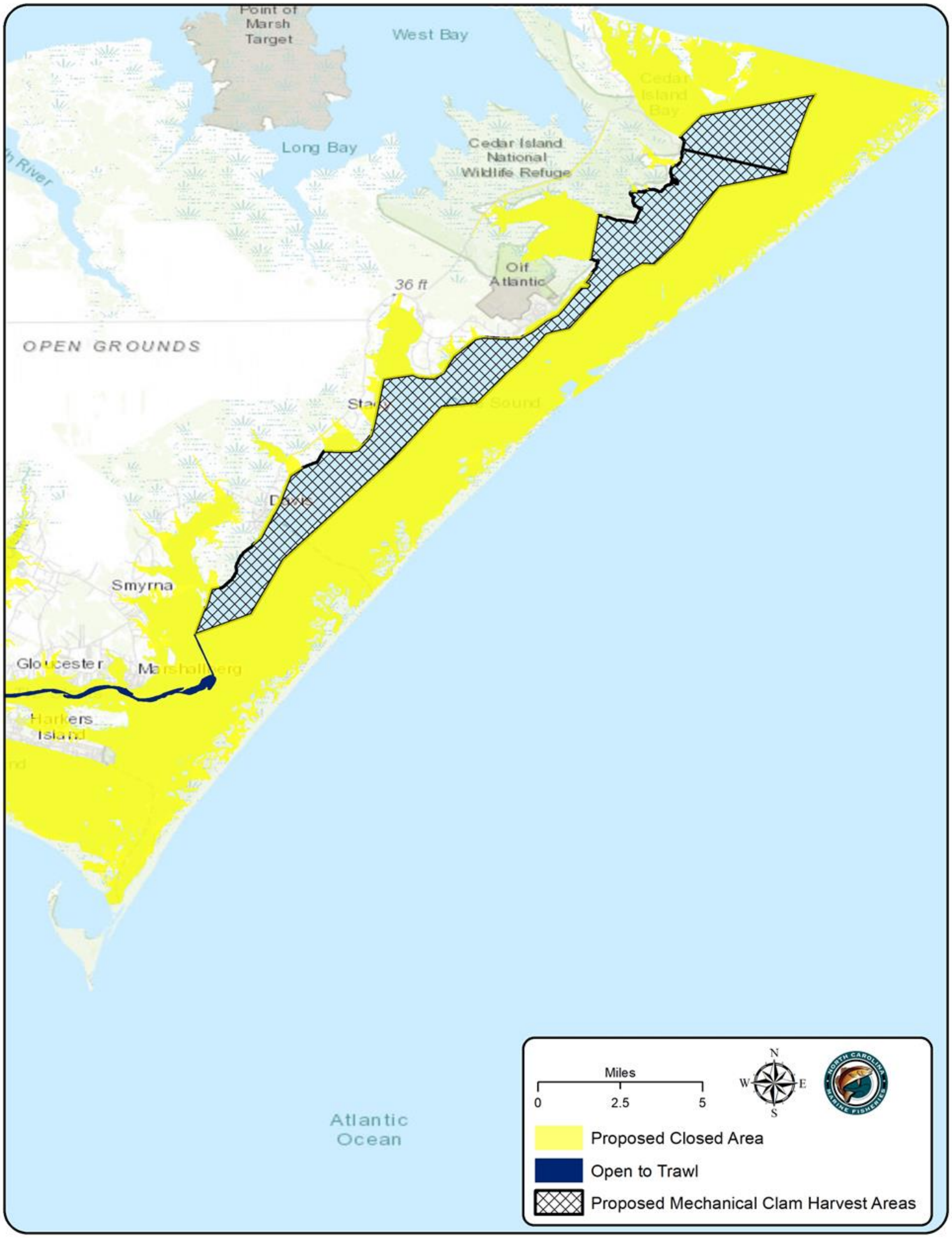

Figure 2.1.3. Location of mechanical clam harvest area in Core Sound.

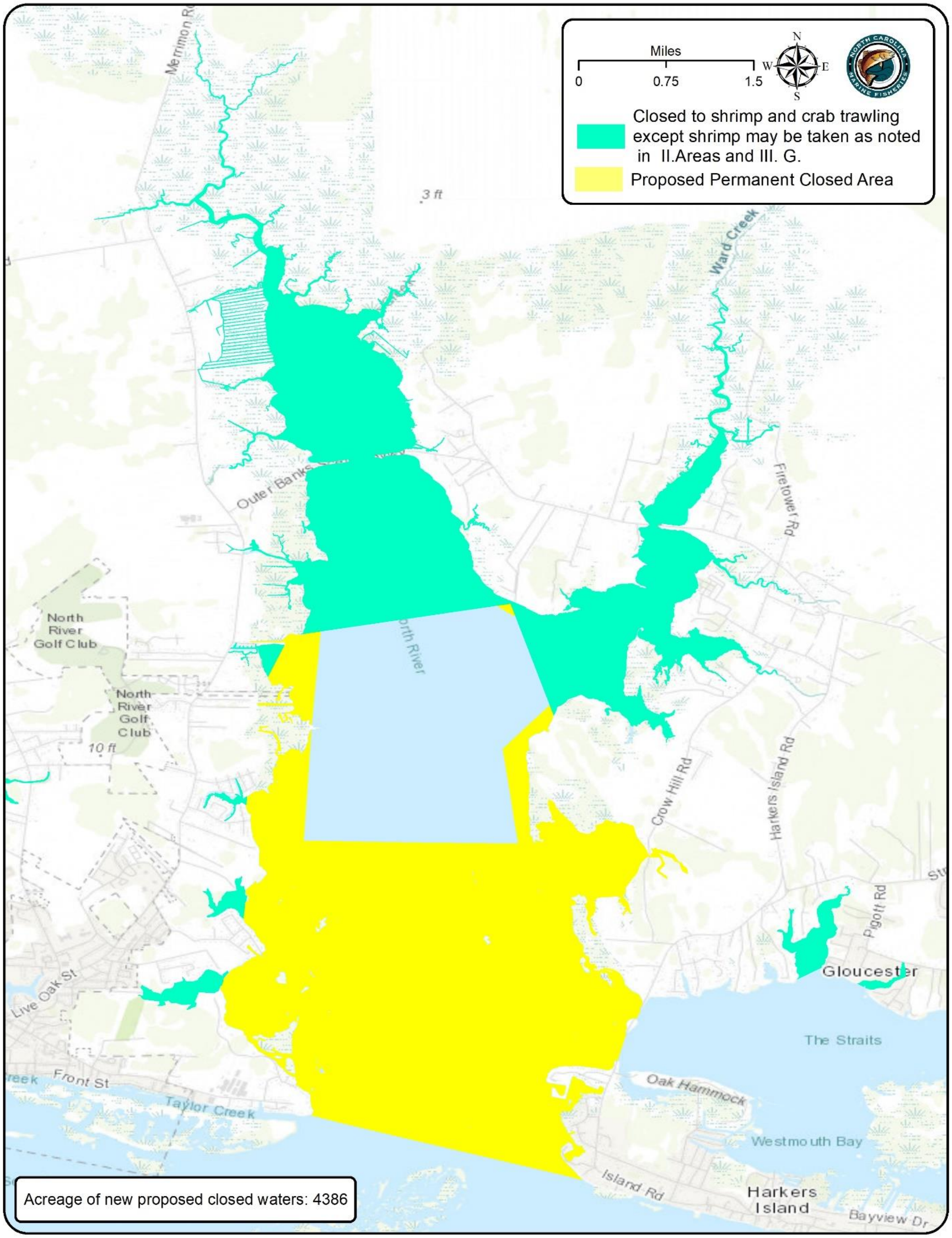

Figure 2.1.4. Location of mechanical clam harvest area in North River.

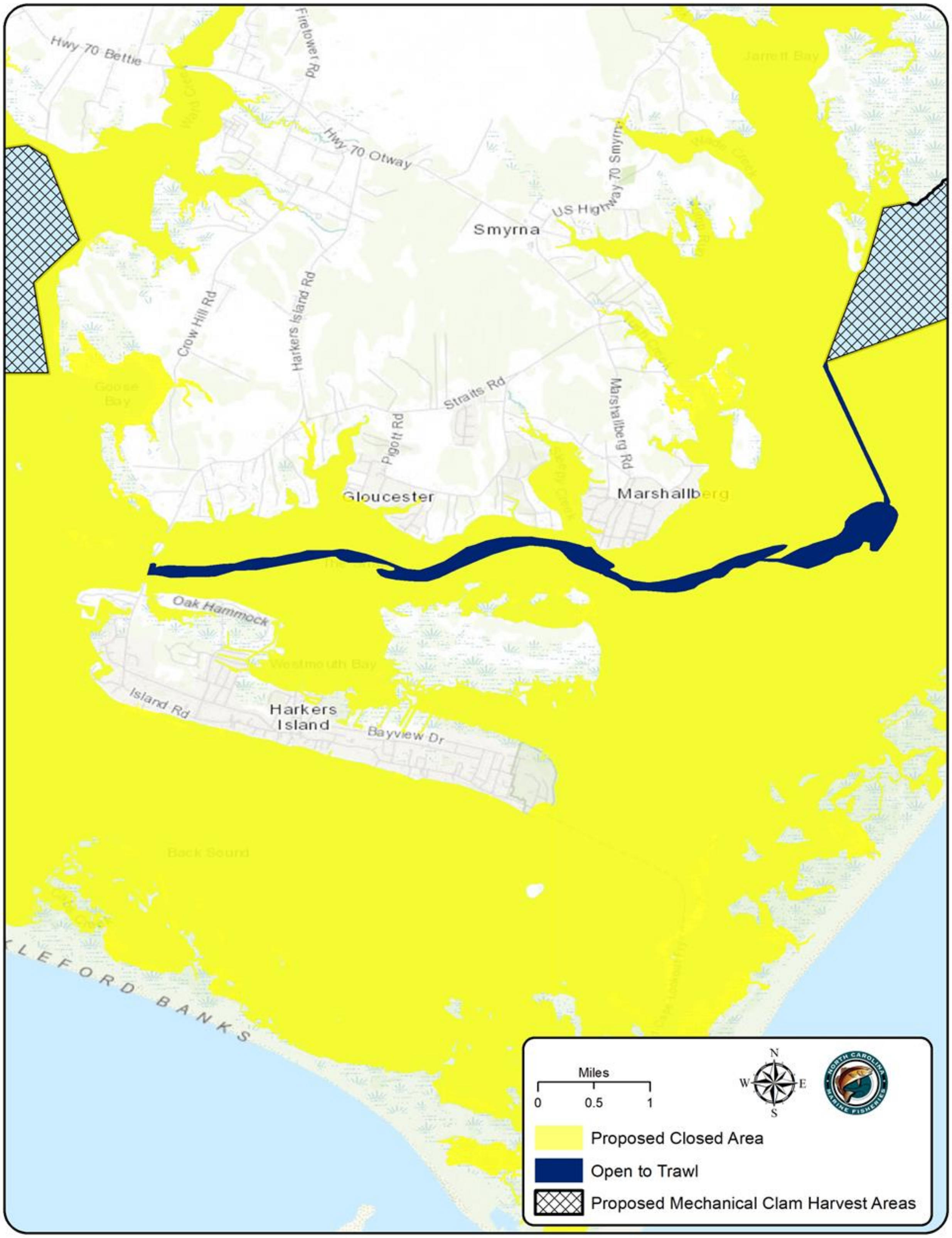

Figure 2.1.5. Location of marked channel in the "Straits".

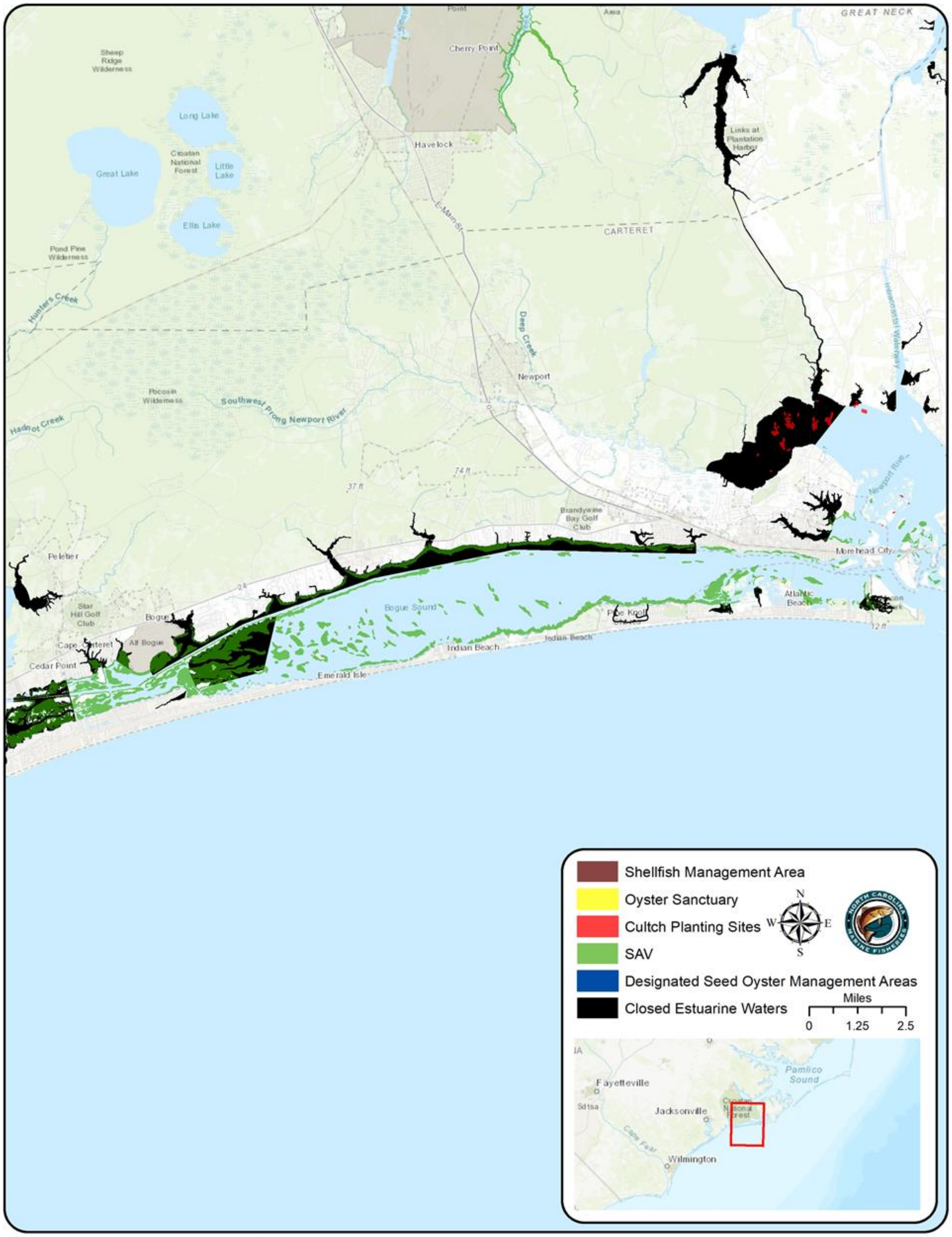

Figure 2.1.6. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in Bogue Sound, NC.

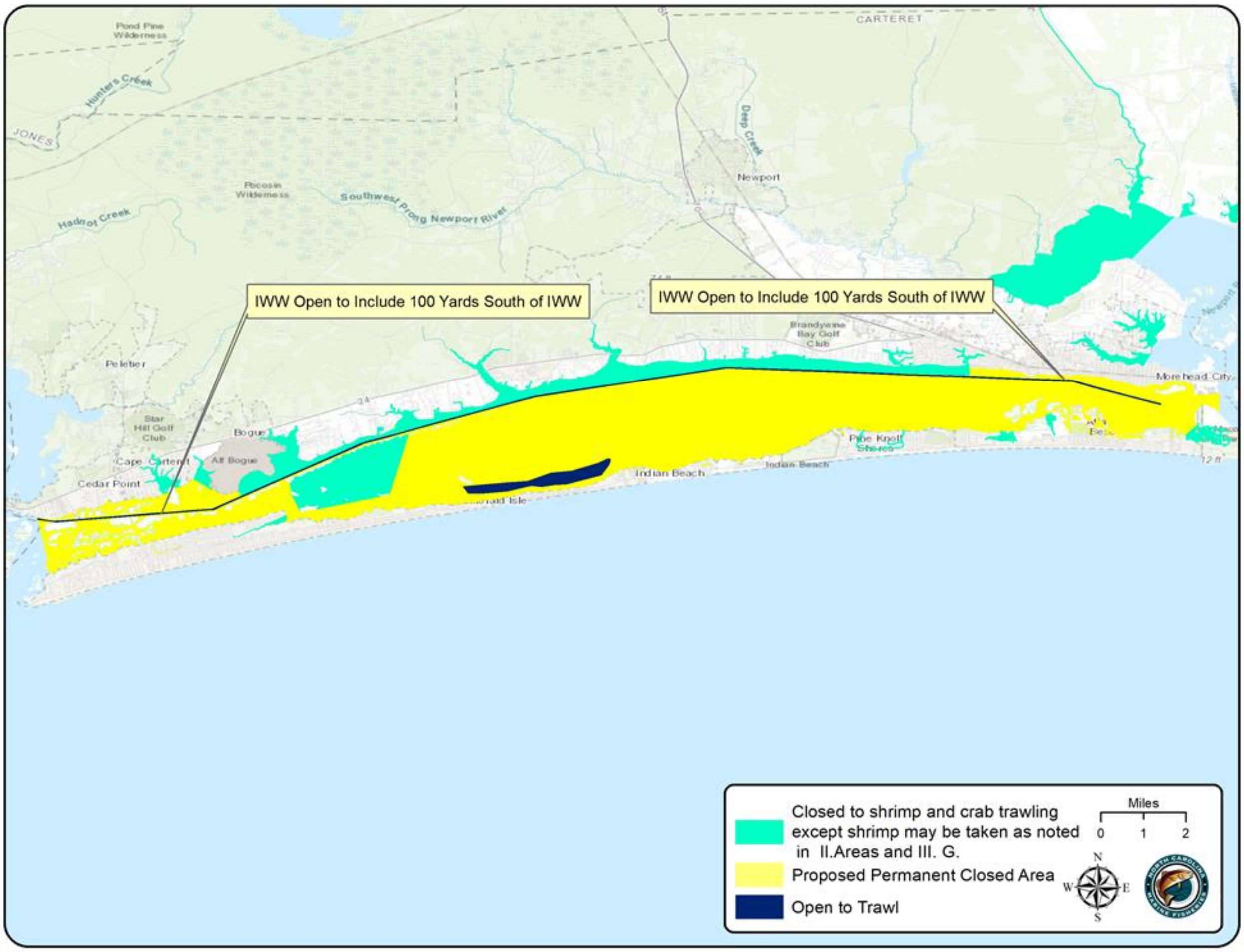

Figure 2.1.7. Proposed shrimp trawl area in Bogue Sound, allowing trawling in the IWW and within 100 yards on the south side of the IWW and in Banks Channel.

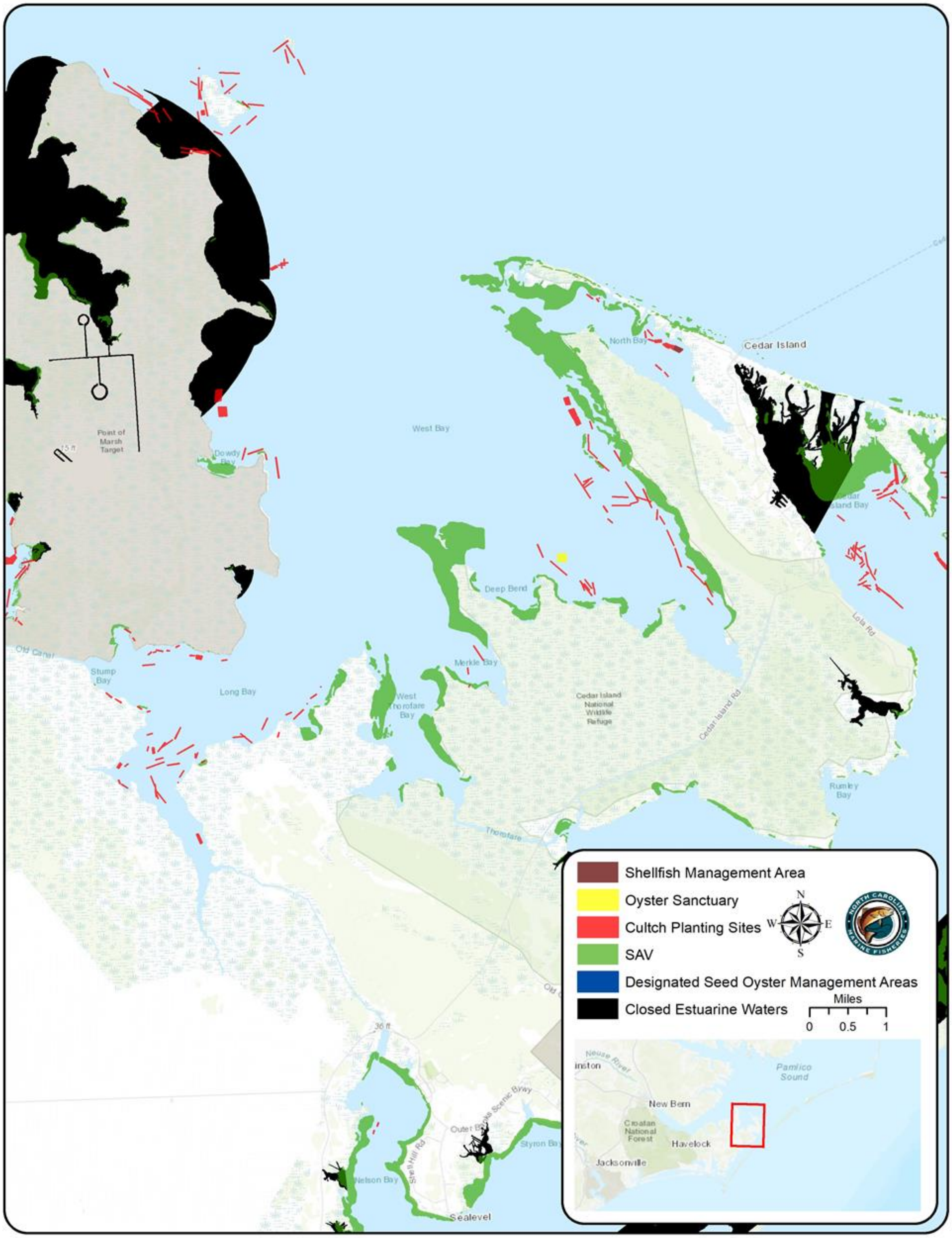

Figure 2.1.8. Designated oyster sanctuary, shellfish and seed oyster management areas and historical SAV locations (since 1981) and cultch planting locations in West Bay, NC.

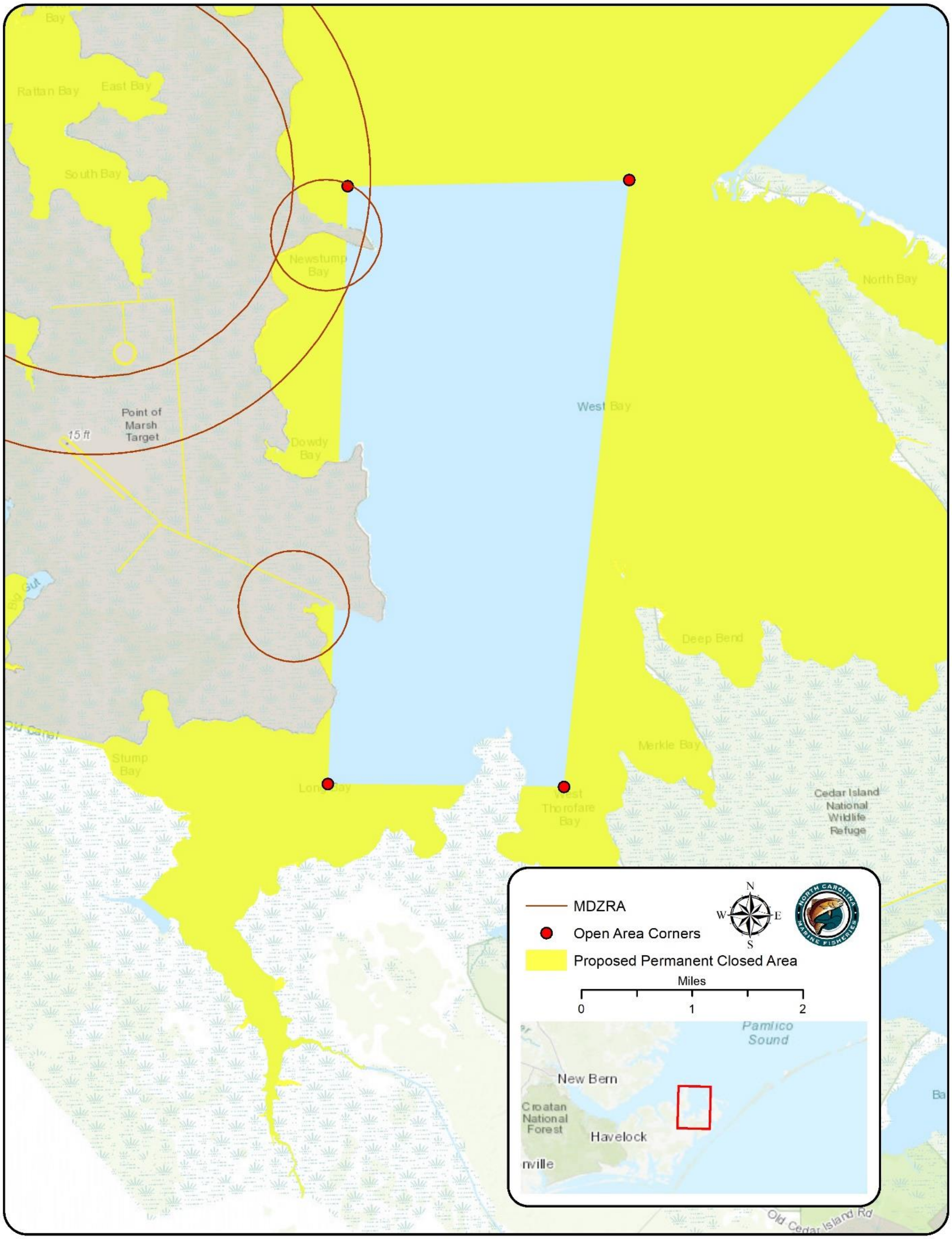

Figure 2.1.9. Example area closure in West Bay to protect SAV and shell bottom habitat.

APPENDIX 2.2. SHRIMP MANGEMENT IN SPECIAL SECONDARY NURSERY AREAS

I. ISSUE

Evaluate current shrimp management in Special Secondary Nursery Areas (SSNA)

II. ORIGINATION

The North Carolina Division of Marine Fisheries (NCDMF) Shrimp Plan Development Team (PDT)

III. BACKGROUND

Primary nursery areas (PNAs), Secondary Nursery Areas (SNAs) and Special Secondary Nursery Areas (SSNAs) are defined in MFC Rule 15A NCAC 03I .0101 and designated in 15A NCAC 03R .0103, .0104, and .0105. It is unlawful to use any trawl net, long haul seine, swipe net, dredge, or mechanical method for clams or oysters for the purpose of taking any marine fishes in PNAs. In SNAs, it is unlawful to use trawl nets for any purpose. However, in SSNAs the Fisheries Director, may, by proclamation, open any or all SSNAs, or any portion thereof to shrimp or crab trawling from August 16 through May 14.

The SNA and SSNA designations are based primarily on the life histories of the same suite of species used in the PNA designations. As these species grow, they begin to move out of PNAs and toward the middle portion of the estuarine bays and sounds (secondary), then into the lower portions of the system (originally called temporary nursery or transport areas), and eventually the ocean (NCDMF 1978; Ross and Epperly 1985). SSNAs were designated to allow shrimping to occur once substantial out-migration of fish had occurred, so as to provide access to the marketable shrimp resource that might otherwise be lost due to out-migration (NCDMF 1978). Areas considered for SSNA designation were those where the shrimp populations would empty into unfishable bottom and where no substantial oyster habitats would be damaged by trawling.

At their February 2020 business meeting the North Carolina Marine Fisheries Commission (NCMFC) changed the designation of 10 SSNAs that had not been opened to trawling in many years to permanent SNAs. Upon final approval, the 2021 Revision to Amendment 1 to the N.C. Shrimp Fishery Management Plan (FMP) will document the rationale and provides supporting data for changing the designations of these SSNAs (unpublished). These rule changes are scheduled to be effective in May 2021. Pending these rule changes, a total of 28,741 acres of SSNAs remain (Table 2.2.1, Figures 2.2.1-2.2.3). This issue paper for Amendment 2 of the shrimp FMP further evaluates the opening of SSNAs to shrimp trawling.

Prior to the 2006 Shrimp FMP, shrimp management strategies focused on maximizing the economic value of the shrimp fishery. With implementation of the 2006 Shrimp FMP, shrimp management by size was developed to address economic conditions in the shrimp fishery and other strategies were implemented to minimize waste though gear modifications [trawl mesh size, bycatch reduction devices (BRD), area closures], culling practices, and harvest restrictions (NCDMF 2006). While size management was carried forward in Amendment 1, the emphasis of the amendment was to address bycatch in the commercial and recreational shrimp fisheries and development of a live bait shrimp fishery (NCDMF 2015).

The criteria for managing opening and closing of SSNAs also shifted with the adoption of Amendment 1, concentrating on minimizing bycatch while also meeting target shrimp sizes (count of shrimp per pound heads-on). Thus, SSNA openings based on division sampling have occurred later in the season (mid-September and October) to address bycatch concerns, particularly in Core and Stump sounds as well as the New River (Table 2.2.2, Figure 2.2.4). While determining openings and closures through the use of count size may be an appropriate management strategy in terms of economics – maximizing the number and size of shrimp caught, is not necessarily an appropriate measure to reduce bycatch because this measure may not reduce the length of a shrimping season. The intent of the rule which established the August 16 through May 14 SSNA opening window was to allow for the migration of juvenile finfish out of the area balanced against shrimp availability and size. Under existing procedures, a warm winter with favorable environmental conditions may lead to an early season opening, while harsh environmental conditions may lead to a later season opening or no opening at all.

Overall, larger shrimp (lower count size) are landed in the northern and central regions of the state (Roanoke, Croatan, Pamlico and Core sounds) with minimal loss of shrimp due to out-migration. However, in the southern region south of New River, shrimp tend to be smaller in size due to the lack of extensive bays and sounds and out-migration can occur over a shorter period of time. Shrimp size also fluctuates more in the southern region in response to environmental conditions. Large volumes of juvenile shrimp are often pushed out of PNAs following excessive rainfall. When this occurs, the event is often over before a closure in an open SSNA can take effect. In other instances, the size of shrimp brought to market may be notably smaller than those observed during NCDMF sampling, prompting requests from fishermen and dealers to close an area shortly after it has opened. In the southern portion of the state, some dealers have reported that smaller shrimp can at times demand a higher price earlier in the season than larger shrimp due to availability. Live shrimp sold for bait, are often smaller, and have higher value than shrimp harvested for consumption (Figure 2.2.5). While delayed openings may allow larger shrimp to be caught later in the season, supply and demand largely determines shrimp prices; therefore, shrimp management by size is not an effective tool for enhancing the value of the shrimp fishery, nor reducing bycatch.

In order to evaluate current shrimp management in SSNAs, it is important to understand that SSNAs are ecologically equivalent to permanent SNAs with similar habitat characteristics and patterns of species diversity and seasonality; only being differentiated by SSNA allowance to be opened seasonally to trawling. Both SSNAs and permanent SNAs are typically located in the middle portion of the estuarine system and are primarily composed of developing sub-adults of similar size that have migrated from an upstream PNA. Ross and Epperly (1985) noted monthly abundances of winter-spawned species such as spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulatus*), southern flounder (*Paralichthys lethostigma*), and blue crab (*Callinectes sapidus*) were similar among trawl stations in the shallow creeks and bays adjacent to Pamlico Sound (Stumpy Point Bay to northern Core Sound), many of which are classified as SSNA and permanent SNAs. Overall, species diversity and seasonality were also found to be similar across all stations. Using cluster analysis to examine the classification of nursery areas in Pamlico and Core sounds as well as portions of the Albemarle Sound, Noble and Monroe (1991) also found that relative species abundance and diversity overlapped at stations with similar abiotic profiles and habitat characteristics (bottom composition, sediment size, depth).

Data from NCDMF Estuarine Trawl Survey (Program 120) was paired into two categories (SSNA and PNA) based on their proximity (< 1 mile) to the SSNAs listed in Table 2.2.1 to evaluate the community structure of finfish and invertebrates at eight stations (4 SSNAs and 4 PNAs) in Core Sound from 1978 to 1981 and Roanoke Sound from 2006 to 2019. Community indices were calculated using methods described by Kwak and Peterson (2007). Data were limited to time periods where sampling was conducted both before and after August 16th. Prior to 1989, sampling was conducted year-around, but was later limited to 104 core stations with sampling only occurring in May and June. However, in the Roanoke Sound temporal coverage was expanded beyond May and June to provide more information on within-year changes in growth, mortality, and abundance of blue crab. A paired t-test was also used to compare the relative abundance (number per sample) and mean lengths of penaeid shrimp (brown, pink, white), Atlantic croaker, southern flounder, spot, summer flounder, and weakfish between nursery types.

A total of 95 species of finfish and crustaceans were collected in SSNAs and 65 species in PNAs. The Margalef Index, a weighted measure of species richness (number of different species) that compensates for differences in sample size (Maragalef 1958; Kwak and Peterson 2007), was also higher for SSNAs, indicating a greater species richness (Table 2.2.3). Species diversity (Shannon Diversity Index *H*'), which accounts for species richness and abundance (Hamilton 2005; Kwak and Peterson 2007) was also higher in SSNAs. Species evenness (Shannon's Index *J*'), an expression of how evenly individuals are distributed among different species (Kwak and Peterson 2007) was higher in SSNAs. Overall, the species composition of both nursery types was similar; however, more unique species were observed in SSNAs. These findings are similar to those of Ross and Epperly (1985) which found that species richness, diversity, and evenness were lower in the uppermost portions of the estuary (i.e., PNAs). The nursery-role of a habitat can vary for species with different life history strategies, degree of estuarine dependency, and use on varying geographic, ontogenetic (physical and psychological), annual and cohort-specific scales (Able 2005). Therefore, SSNAs may not only serve as important migration corridors for winter spawned species, but also as nursery areas for spring and summer spawned species.

Based on the results of the paired t-tests, the relative abundance of Atlantic croaker, southern flounder, summer flounder, and weakfish was not significantly different between SSNAs and PNAs (Table 2.2.4). In SSNAs, relative abundance of southern flounder, spot, summer flounder, and weakfish peaked in May and June; however, Atlantic croaker peaked in October (Figure 2.2.6). The relative abundance of brown and white shrimp in SSNAs peaked in June and July, respectively, declining rapidly after August and September. The mean length of southern flounder as well as brown, pink, and white shrimp was not significantly different between nursery types (Table 2.2.4). Length frequency distribution of target species was similar for target species in both nursery types (Figure 2.2.7). These results further support the ecological similarity between SSNAs and PNAs and demonstrates the importance of both habitats as essential habitat for many developing sub-adult finfish and invertebrates at their various life stages throughout the year.

The presence of juvenile fish is not the only factor that is considered when identifying nursery areas. In addition to species abundance, size composition, and species diversity, several abiotic factors (bottom type, sediment size, salinity, temperature, and depth) must be evaluated for an area to be designated a PNA. As ecosystem science advances, it has been found that in addition to these factors, other things such as growth, predator protection, and movement out of the nursery into the adult habitat influence determination of nursery areas. Based on Beck et al. (2001), Dahlgren et al. (2006), and Peterson (2003), nursery areas are a subset of juvenile habitat that contributes disproportionally more to the production of juveniles that recruit into a population than another area of similar size. Once a waterbody has been identified by NCDMF as a potential nursery area, a sampling station is established and is sampled a minimum of three years prior to designation to account for annual variability. This process also includes comparisons to other nursery areas to ensure consistent application of the methodology (NCDMF 2013). Since SSNAs are a subset of SNAs, no further sampling or analysis is needed to change the remaining SSNAs to permanent SNAs. Additionally, SNAs do not have additional protections from other agencies' rules, except for a North Carolina Coastal Resources Commission (CRC) rule that restricts impacts to secondary nursery areas (among several other natural resources areas) in the siting of energy facilities [7M .0403 (f)(10)(A)].

Changing the designation of SSNAs to PNAs or expanding nursery area designations is outside of the scope of the Shrimp FMP. The Coastal Habitat Protection Plan (CHPP) provides the proper framework to assist the Marine Fisheries, Environmental Management, and Coastal Resources commissions in managing fish habitat for continued protection and restoration. In addition, an objective of this amendment is to develop a strategy through the CHPP to review current nursery areas and to identify and evaluate potential areas suitable for designation. Efforts are currently underway to create a multi-metric index that will describe the ecological condition of Strategic Habitat Areas (SHAs). SHAs are a subset of high quality or rare, relatively unaltered habitats or systems of habitats that support estuarine and coastal fish and shellfish species. The multi-metric index will evaluate several variables including community diversity, species richness, and feeding guilds (species that share similar niches or ecological roles). A similar process will also be used describe the ecological condition of PNAs, SNAs, and non-nursery areas. Additional work will focus on evaluating current nursery area designations and better aligning the current approach of designating nursery areas in North Carolina with the most current science.

See the CHPP for additional information on protection of critical habitats as well as the identification of SHAs. The Coastal Habitat Protection Plans and Source Document can be viewed and downloaded from: http://portal.ncdenr.org/web/mf/habitat/chpp/downloads.

IV. AUTHORITY

North Carolina General Statutes

§ 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

North Carolina Marine Fisheries Commission Rules
15A NCAC 03H .0103 PROCLAMATIONS, GENERAL
15A NCAC 03L .0101 SHRIMP HARVET RESTRICTIONS
15A NCAC 03J .0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS
15A NCAC 03N .0105 PROHIBITED GEAR, SECONDARY NURSERY AREAS

V. DISCUSSION

- Section discusses potential management measures to reduce bycatch in SSNAs
- Establishing static seasons with delayed openings could reduce bycatch and allow access to larger more markable shrimp later in the season
- Changing the designation of all SSNAs to permanent SNAs would eliminate bycatch by making it unlawful to use any trawl (beam, crab, skimmer, otter, etc.)
- The amount of bycatch reduction is non-quantifiable (see *Appendix 1: Shrimp Trawl Bycatch Assessment*)
- Changing the designation of all SSNAs to permanent SNAs would require gill net attendance in all waters from May 1 through November 30

By allowing limited trawling in SSNAs, fishermen may catch shrimp late in the season that have not migrated out into the larger estuaries. The division conducts regular sampling in the central and southern regions of the state to monitor abundance of bycatch and shrimp size and abundance if the area is being considered for opening. Target sizes (count of shrimp per pound heads-on) differ by waterbody within the state to account for variability in size preference of user groups, geographic differences in shrimp size at migration, weather events, vessel sizes, and socioeconomic conditions (NCDMF 2006). Timing of SSNA openings can be highly influenced by environmental conditions, proximity to major inlets and rivers, and input from stakeholders, and vary by area. In smaller waterbodies of the state, shrimp tend to migrate earlier due to lack of extensive bays and sounds. Management by target size has been controversial because of bycatch, variability in shrimp abundance and size from year to year, timing of opening, user conflicts, and pressure from fishermen to access the resource.

Using the NCTTP landings data, the monthly percentage of shrimp harvested in all estuarine waters that were a 31/35 count or lower (average target opening size for SSNAs listed in Table 2.2.1) was calculated from 1994 to 2019 (Table 2.2.5). While landings data for each SSNA could not be identified, count sizes were used as a proxy for shrimp sizes in SSNAs. On average, 69% of the shrimp landed from August 1 to May 31 were a 31/35 count or lower (Table 2.2.5). If a September 1 to November 30 season was in place, approximately 81% of the shrimp landed would be a 31/35 count or lower. Approximately 85% of the shrimp landed would be a 31/35 count or lower if the season was delayed to October 1 to December 31. In the southern portion of the state, marketable shrimp typically migrate out of the estuaries earlier in the year; thus, seasons could be established regionally to account for differences in migration timing.

While many SSNAs have periodically opened from 2000 to 2019, several have not opened to shrimp trawling in many years (Tables 2.2.1 and 2.2.2). The North River and Ward Creek SSNAs have only opened once since 2000. The Chadwick Bay SSNA has only opened twice since being designated a SSNA in 2011; last opening in 2012. The Kitty Hawk/Buzzards Bay SSNA has never opened since being designated as nursery area in 2004. In the Stump Sound SSNA, the area from the Highway 210 Bridge to Marker #49 has only opened twice in the last five years; opening in 2018 to allow access to shrimp prior to Hurricane Florence. The presence of small shrimp and high levels of bycatch, as well as limited stakeholder demand have minimized the need to open most SSNAs. Changing these particular SSNA designations to permanent SNAs would have little to no impact on commercial shrimp and crab trawling since these areas have not been opened to trawling in many years. Not allowing trawling in these areas would also provide further protection to critical habitats used by numerous economically important species of fish and invertebrates as well as other prey species. Furthermore, eliminating bottom disturbing gear such as crab and shrimp trawling in these areas would provide additional protection to significant portions of MFC nominated SHAs.

Re-designating all SSNAs to permanent SNAs, making it unlawful to use all trawl nets for any purpose, would further reduce bycatch and protect developing sub-adult finfish and invertebrates that have migrated from PNAs and critical fish habitats. Re-designating all SSNAs to permanent SNAs would also provide further protection to species such as Atlantic Croaker that migrate through SSNAs into PNAs in September (Figure 2.2.6). However, changing the designation of all SSNAs to permanent SNAs would impact commercial shrimp trawling; most notably in SSNAs located in Core and Stump sounds, and the New River. Overall, SSNAs make up a small percentage of the total acreage of North Carolina’s estuarine waters open to trawling (Table 2.2.1). Closing these areas to trawling leaves a considerable amount of water open to trawling and potentially allows more markable shrimp to be harvested downstream of the current SSNA boundaries. Currently, only skimmer trawls are allowed in the New River SSNA; prohibiting the use of all trawls could elevate conflicts between otter and skimmer trawlers downstream.

Changing the designation of all SSNAs to permanent SNAs would eliminate crab trawling in some areas. However, effort in the crab trawl fishery has been low in recent years with most effort occurring in the central region of the state (Core and Bogue sounds; Table 2.2.6). Statewide, blue crab landings from crab and shrimp trawls account for 0.05% and 0.1%, respectively of the total blue crab harvest in recent years (NCDMF 2020). Since 2009, there have been no landings from crab trawling in the New River, Chadwick Bay, and Stump Sound, though it is allowed. With the adoption of Amendment 3 to the Blue Crab FMP in 2020, the use of crab trawls was prohibited north of the shrimp trawl lines in the Pamlico, Pungo, and Neuse rivers (NCDMF 2020). This action was taken to improve habitat conditions for blue crabs as well as other economically important species and provide additional protection of SHAs. Trawling has also been further limited to November through February in fourteen inlets from Beaufort Inlet south to the NC/SC line with the inception of new crab spawning sanctuaries on May 1, 2020.

Attendance requirements for gill nets would also change if SSNAs were reclassified to permanent SNAs (Table 2.2.7). Current gill net attendance requirements for each SSNA are shown in Figures 2.2.8-2.2.10. MFC Rules 15A NCAC 03J .0103 and 03R .0112 require attendance of small mesh gill nets in all permanent SNAs. The 2001 Red Drum FMP implemented small mesh gill net attendance from May 1 through October 31 (later extended through November) in areas where juvenile red drum (*Sciaenops ocellatus*) typically occur, in shallow bays and creeks, shorelines, and over shallow submerged aquatic vegetation (NCDMF 2001). Additionally, the South Atlantic Fishery Management Council (SAFMC) designated specific inshore areas in the south Atlantic region as Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) in their Habitat Plan for red drum (SAFMC 1998). In North Carolina, these federal areas included all state-designated nursery habitats of particular importance for red drum (i.e., all PNAs and all SNAs). When the gill net attendance rule language was adopted, it covered areas listed as PNAs and SNAs, but not SSNAs. The stated rationale for red drum bycatch reduction would apply to any SNA (past or future).

VI. PROPOSED RULE(S)

Completed after recommendations are brought forward.

VII. MANAGEMENT OPTIONS AND IMPACTS

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

1. *Status quo* - Continue to manage special secondary nursery concentrating on minimizing bycatch while also meeting target shrimp sizes with sampling.
   - \+ No rule changes are needed
   - \+ No impact to commercial fishermen
   - \+ Flexibility in dealing with dynamic conditions
   - \- Does not minimize bycatch from shrimp trawls in SSNAs
   - \- Does not address the needs of all user groups (bait vs. consumption)
   - \- Does not protect habitat from bottom disturbing gear
   - \- Labor intensive and expensive sampling
   - \- Shrimp abundance and size vary widely in the same geographic area
   - \- Bycatch abundance variable due to environmental conditions and locations in the estuary

2. Establish static seasons for shrimp trawling in all or some special secondary nursery areas.
   - \+ Potential to reduce bycatch from shrimp trawls in SSNAs
   - \+ Potential to increase harvest size and economic value of shrimp
   - \+ Opening and closing dates predetermined
   - \+ Satisfy fishermen who disagree with flexible openings.
   - \+ Minimizes confusion of openings
   - \- Does not protect habitat from bottom disturbing gear
   - \- No flexibility in dealing with dynamic conditions
   - \- Potential for excessive harvest of small shrimp or shrimp gone when opened
   - \- May adversely impact some fishermen more than others

3. Change the designation of all or some special secondary nursery areas to permanent secondary nursery areas which would prohibit all trawling. Under MFC Rule 03R .0112(b)(1), gill net attendance is required in all waters of permanent secondary nursery areas from May 1 through November 30.

+ Eliminate bycatch from shrimp trawls in all SSNAs
+ Protects habitat from bottom disturbing gear
+/- Gill net attendance required in all waters from May 1 through November 30
+ Nursery rule changes are needed
- Eliminates crab trawling when the areas are open
- Loss of income to commercial fishermen and dealers
- Cannot assess benefit of bycatch reduction on fish stocks with current data
- Loss of recreational shrimp source
- May concentrate participants into open areas and result in greater effort impacts overall
- May adversely impact some fishermen more than others

VIII. SHRIMP FMP WORKSHOPS

Shrimp FMP Workshops were held in March 2021 between the division plan development team and the Shrimp FMP Advisory Committee (AC). The goal of these workshops is for the AC to assist the division in drafting the plan. The division had distinct discussion points to lead conversation to inform individual issue papers where stakeholder input was needed. The guidance received during workshops on the management of SSNAs were incorporated into the draft plan. Overall, AC members expressed the need for additional biological and economic data for SSNAs. There was mixed support between redesignating SSNAs to SNAs and using static seasons. Clarification between what is appropriate in this plan and the CHPP were noted. Commercial AC members indicated that while they would like to see SSNAs openings occur earlier and more frequently, changes to current strategies used to manage SSNAs is not needed. Commercial AC members also noted that the use of skimmer trawls in SSNAs may reduce bycatch in SSNAs.

IX. RECOMMENDATION

The division will make recommendations after receiving input from the public and the MFC Advisory Committees.

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Tables

Table 2.2.1. Total acreage, year designated, percent (%) acreage of estuarine waters open to trawling, year designated, last year opened, and target opening sizes (count of shrimp per pound heads-on) of special secondary nursery areas.

Current Rule ID 03R .0105	Description	Acreage	Percent Acreage of Estuarine Waters Open to Trawling	Year Designated (reclassified)	Latest Year Opened	Proclamation Reference	Target Count size
1 (a)	Shallowbag Bay	468	0.04	2004	2017	SH-5-2017	27-35
1 (b)	Kitty Hawk Bay-Buzzard Bay	1,996	0.18	2004			27-35
3 (a)	West Thorofare Bay	776	0.07	1986	2018	SH-6-2018	27-35
3 (b)	Long Bay-Ditch Bay	1,140	0.10	1986	2018	SH-6-2018	27-35
3 (c)	Turnagain Bay	963	0.09	1995	2018	SH-6-2018	27-35
4 (a)	Cedar Island Bay	1,794	0.16	1986	2018	SH-6-2018	27-35
4 (b)	Thorofare Bay-Barry Bay	2,156	0.19	1986	2018	SH-6-2018	27-35
4 (c)	Nelson Bay	1,077	0.10	1986	2018	SH-6-2018	27-35
4 (d)	Brett Bay	251	0.02	1986	2018	SH-6-2018	27-35
4 (e)	Jarrett Bay	1,431	0.13	1986	2018	SH-6-2018	27-35
5 (a)	North River	978	0.09	1986	2000	SH-4-2000	27-35
5 (b)	Ward Creek	625	0.06	1986	2000	SH-4-2000	27-35
7	New River (above HWY 172 Bridge)**	14,669	1.31	1995	2019	SH-7-2019	20-30
8	Chadwick Bay	167	0.01	2011	2012	SH-8-2012	30-40
9	Intracoastal Waterway (Stump Sound)	252	0.02	1995	2019	SH-7-2019	20-30

* Not opened after SSNA designation
**Only 5,406 acres is open to trawling or 0.48% of estuarine waters open to trawling

Table 2.2.2. Special secondary nursery (SSNA) openings by waterbody, 2000-2019. Re-openings are bolded.

	Total Openings	Not Opened	Opened Aug. 16	Openings Aug. 1-16	Aug. 17-31	Sept. 1-16	Sept. 17-30	Oct. 1-16	Oct. 17-31	Nov. 1-16	Nov. 17-30	Dec. 1-16
Roanoke Sound Area												
Shallowbag Bay	13	2	8	8	5							
Kitty Hawk Bay-Buzzard Bay	0	20	0									
Core Sound Area												
West Thorofare Bay[4]	17	3	0				2	6	7	1		
Long Bay-Ditch Bay[4]	17	3	0				2	6	7	1		
Turnagain Bay[4]	17	3	0				2	6	7	1		
Cedar Island Bay[4]	17	3	0				2	6	7	1		
Thorofare Bay-Barry Bay[4]	17	3	0				2	6	7	1		
Nelson Bay[4]	17	4	0				2	6	7	1		
Brett Bay[4]	17	3	0				2	6	7	1		
Jarrett Bay[4]	17	3	0				2	6	7	1		
North River Area												
North River	1	19	1	1								
Ward Creek	1	19	1	1								
New River Area												
New River (above HWY 172 Bridge)[1]	21	0	0		10	5	2	2(**1**)	1			
New River (Hine to Lowe Point)[2]	1	19	0			1						
Chadwick Bay	2	7	0		2							
Stump Sound (IWW)												
Marker 17 to HWY 50 Bridge (total)	3	17	0		3							
Marker 17 to HWY 50 Bridge (total in parts)	8	12	0			1		1		1	2	3
Marker 17 to Marker 49 (upper, middle)[3]	1	19	0			1						
Marker 17 to HWY 210 Bridge (upper)	20	0	2	2	9	5	1	1	2			
HWY 210 Bridge to Marker 45 (middle)[1]	13	9	0		3	1		1		1(**1**)	2(**1**)	3
HWY 210 Bridge to Marker 49 (middle)	11	9	0		3	1		1		1	2	3
Marker 45 to HWY 50 Bridge (lower)[1]	16	5	1	1	7	3		1	1			**2(1)**
Marker 49 to HWY 50 Bridge (lower)	15	5	1	1	6	3		1		1	2	1

[1] Closed and reopened within year due to small shrimp and bycatch concerns
[2] Partial opening of SSNA on 9/3/2004, full opening on 9/14/2004
[3] Opened on 9/5/18 for Hurricane Florence
[4] Opened on 9/12/18 for Hurricane Florence

Table 2.2.3. Total number of samples collected, total species abundances, species richness, species diversity, and species evenness of Special Secondary Nursery Areas (SSNA) and Primary Nursery Areas (PNA) located in Core (1978-1981) and Roanoke sounds (2006-2019).

	SSNA	PNA
Total Samples	251	250
Abundance		
Total Number of Individuals	31,013	18,410
Species Richness		
Total Species	95	65
Margalef Index	9.09	6.52
Species Diversity		
Shannon Diversity Index (*H'*)	2.83	1.77
Species Evenness		
Shannon's Index (*J'*)	0.62	0.42

Table 2.2.4. Relative abundance (number per sample), standard error (SE), percent standard error (PSE), total number collected (N), number measured, modal length (mm), mean length (mm), size range (mm) for economically important species collected in NCDMF Program 120 in Core (1978-1981) and Roanoke sounds (2006-2019). Bolded relative abundance and mean length values are statistically significant ($p < 0.05$).

Common Name	Relative Abundance	SE	PSE	Number Collected	Sample Size	Number Measured	Mode (mm)	Mean Length (mm)	Size Range (mm)
SSNA									
Brown Shrimp	**7.2**	1.2	16	1,813	251	1,574	25	66.8	5-138
Pink Shrimp	**1.0**	0.2	17	245	251	244	35	57.9	15-145
White Shrimp	**1.9**	0.6	33	470	251	366	24	50.7	15-162
Atlantic Croaker	7.3	1.3	18	1,833	251	1,302	25	**60.3**	10-265
Southern Flounder	0.4	0.1	26	99	251	99	59	83.8	37-380
Spot	**17.0**	2.7	16	4,259	251	2,381	55	**63.6**	12-215
Summer Flounder	0.1	0.0	37	17	251	17	43	**91.1**	53-197
Weakfish	0.2	0.1	50	50	251	50	45	**54.1**	25-209
PNA									
Brown Shrimp	**4.6**	0.6	14	1,152	250	1,150	65	67.3	13-155
Pink Shrimp	**0.3**	0.1	23	77	250	77	35	56.1	25-168
White Shrimp	**0.4**	0.1	26	107	250	35	37	53.1	24-99
Atlantic Croaker	6.6	1.0	16	1,639	250	1,379	22	**70.3**	7-245
Southern Flounder	0.1	0.0	17	35	250	107	75	86.1	29-453
Spot	**26.7**	3.9	15	6,666	250	3,673	55	**69.4**	16-200
Summer Flounder	0.1	0.0	35	13	250	13	66	**68.8**	38-116
Weakfish	0.1	0.0	33	20	250	20	45	**89.7**	22-188

Table 2.2.5. Total estuarine shrimp landings and count size (number of shrimp per pound, heads-on), 1994-2019. NUM/DOZ=dozens of shrimp sold as live bait converted to pounds.

	Month											
	1		2		3		4		5		6	
Size	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%
0/15	47,154	19.1	10,449	32.8	12,066	7.7	38,009	6.4	26,575	1.4	101,545	1.3
16/20	102,216	41.5	7,053	22.1	18,122	11.6	50,517	8.5	79,783	4.2	322,792	4.2
21/25	55,956	22.7	6,733	21.1	10,708	6.8	25,072	4.2	106,788	5.7	638,028	8.3
26/30	4,344	1.8	1,380	4.3	8,175	5.2	18,739	3.1	176,800	9.4	1,043,711	13.5
31/35	21,563	8.8	1,152	3.6	4,937	3.2	36,465	6.1	251,733	13.4	961,695	12.5
36/40	4,639	1.9	636	2.0	12,625	8.1	89,913	15.0	345,570	18.4	1,050,185	13.6
41/45	4,954	2.0	514	1.6	19,586	12.5	94,863	15.9	299,495	16.0	839,595	10.9
46/50	1,986	0.8	489	1.5	17,906	11.4	129,512	21.7	327,509	17.4	975,897	12.6
51/55	916	0.4	1,913	6.0	17,891	11.4	25,754	4.3	57,731	3.1	336,663	4.4
56/60	90	0.0	711	2.2	11,585	7.4	21,059	3.5	34,873	1.9	562,452	7.3
60/70	101	0.0	281	0.9	3,773	2.4	2,854	0.5	17,307	0.9	397,094	5.1
70/80		0.0	4	0.0	230	0.1	197	0.0	5,483	0.3	136,455	1.8
80+		0.0		0.0	147	0.1	2,466	0.4	3,623	0.2	45,663	0.6
MIXED	1,962	0.8	475	1.5	18,675	11.9	61,568	10.3	142,888	7.6	304,045	3.9
NUM/DOZ	409	0.2	63	0.2	224	0.1	604	0.1	1,224	0.1	4,051	0.1
Total	246,289	100	31,852	100	156,648	100	597,592	100	1,877,381	100	7,719,869	100
Size < 31/35	231,231	93.9	26,767	84.0	54,008	34.5	168,802	28.2	641,678	34.2	3,067,770	39.7

	Month											
	7		8		9		10		11		12	
Size	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%	lbs.	%
0/15	3,637,516	8.7	8,771,235	24.1	4,999,151	21.7	7,869,400	39.6	4,118,059	48.3	451,226	31.3
16/20	9,708,484	23.2	11,291,889	31.0	4,927,747	21.4	3,634,021	18.3	1,162,558	13.6	360,609	25.0
21/25	11,433,320	27.3	6,191,082	17.0	3,906,628	16.9	2,633,966	13.2	923,615	10.8	308,675	21.4
26/30	8,233,091	19.7	3,216,202	8.8	2,030,047	8.8	974,281	4.9	292,217	3.4	44,749	3.1
31/35	2,700,684	6.4	1,118,548	3.1	1,677,016	7.3	1,486,633	7.5	643,622	7.6	76,541	5.3
36/40	2,444,248	5.8	1,234,049	3.4	1,467,136	6.4	1,174,098	5.9	431,511	5.1	57,786	4.0
41/45	653,750	1.6	642,456	1.8	892,771	3.9	577,994	2.9	244,930	2.9	33,582	2.3
46/50	885,838	2.1	779,181	2.1	730,163	3.2	426,681	2.1	128,316	1.5	20,138	1.4
51/55	183,318	0.4	360,530	1.0	387,263	1.7	138,488	0.7	90,234	1.1	20,223	1.4
56/60	341,249	0.8	519,438	1.4	420,795	1.8	215,100	1.1	106,857	1.3	19,317	1.3
60/70	174,122	0.4	475,245	1.3	467,507	2.0	182,927	0.9	95,971	1.1	15,087	1.0
70/80	49,647	0.1	228,867	0.6	234,544	1.0	56,322	0.3	53,564	0.6	2,891	0.2
80+	41,897	0.1	173,485	0.5	235,186	1.0	38,224	0.2	38,691	0.5	2,236	0.2
MIXED	1,385,882	3.3	1,403,106	3.9	672,985	2.9	475,262	2.4	181,996	2.1	24,372	1.7
NUM/DOZ	3,543	0.0	3,063	0.0	2,534	0.0	5,478	0.0	9,050	0.1	3,096	0.2
Total	41,876,591	100	36,408,376	100	23,051,472	100	19,888,875	100	8,521,190	100	1,440,528	100
Size < 31/35	35,713,095	85.3	30,588,955	84.0	17,540,588	76.1	16,598,302	83.5	7,140,071	83.8	1,241,800	86.2

Table 2.2.6. Annual crab and peeler trawl landings by region, 2009-2019.

	ASMA[1]		Pamlico Sound Region[2]		Core/Bogue Sound to New River[3]		New River to SC State line[4]	
Year	Participants	Trips	Participants	Trips	Participants	Trips	Participants	Trips
2009	4	17	57	430	3	37	0	0
2010	3	11	29	143	25	150	0	0
2011	2	3	20	123	20	143	0	0
2012	3	3	9	17	5	25	0	0
2013	1	2	12	42	9	70	0	0
2014	0	0	23	58	17	165	0	0
2015	1	1	28	109	25	380	0	0
2016	2	2	20	84	23	391	0	0
2017	0	0	19	71	21	297	0	0
2018	1	1	8	10	20	168	0	0
2019	6	27	17	74	19	222	0	0

[1] All the waters north of Pamlico Sound
[2] Pamlico Sound, Pamlico River, Pungo River, Neuse River, and Bay River
[3] Core Sound, Bogue Sound, Newport River, North River, White Oak River, New River, Inland Waterway-Onslow
[4] Masonboro Sound, Topsail Sound, Cape Fear River, Shallotte River, Lockwood’s Folly River, Stump Sound (IWW), and Brunswick County (IWW)

Table 2.2.7. Current and potential gill net attendance requirement changes (<5 inch stretched mesh) for each special secondary nursery area under consideration for reclassification by management option.

Management Options	Shallowbag Bay	Kitty Hawk Bay-Buzzard Bay	West Thorofare Bay	Long Bay-Ditch Bay	Turnagain Bay	Cedar Island Bay	Thorofare Bay-Barry Bay	Nelson Bay
Current gill net attendance requirements	Attendance not required	Attendance not required	Attendance within 50 yards of shore from May 1 - November 30	Attendance within 50 yards of shore from May 1 - November 30	Attendance within 200 yards from shore in all waters year round	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30
Options 1 & 2: Remain as SSNAs*	No change	No change	No change	No change	No change	No change	No change	No change
Option 3: Reclassify as SNAs† with gill net attendance	Gill net attendance period in all waters from May 1 - November 30	Gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	No change	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30

Management Options	Brett Bay	Jarrett Bay	North River	Ward Creek	New River (above HWY 172 Bridge)	Chadwick Bay	Intracoastal Waterway (Stump Sound)
Current gill net attendance requirements	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30	Attendance within 50 yards of shore from May 1 - September 30
Options 1 & 2: Remain as SSNAs*	No change	No change	No change	No change	No change	No change	No change
Option 3: Reclassify as SNAs† with gill net attendance	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30	Extends gill net attendance period in all waters from May 1 - November 30

* Special Secondary Nursery Area
† Secondary Nursery Area

Figures

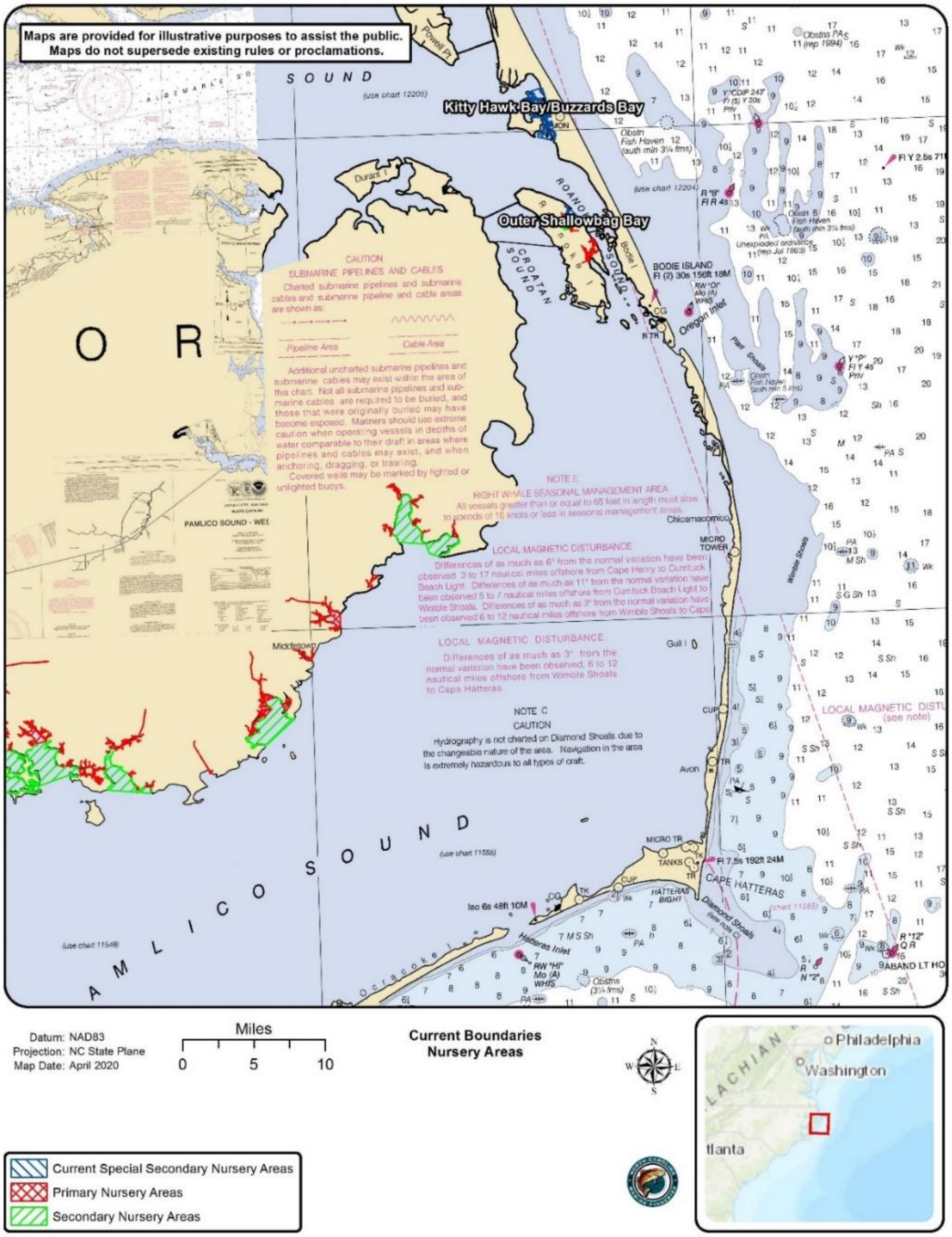


Figure 2.2.1. Map of the shrimp management and nursery areas in the Roanoke Sound that are subject to gill net attendance rules (<5 inch stretched mesh). Gill net attendance will be required in all areas marked as special secondary nursery areas (SSNAs) from May 1 through November 30 if their designation is changed to permanent secondary nursery areas (SNAs). Year-round attendance (<5 inch stretched mesh) is already required in Scranton Creek.

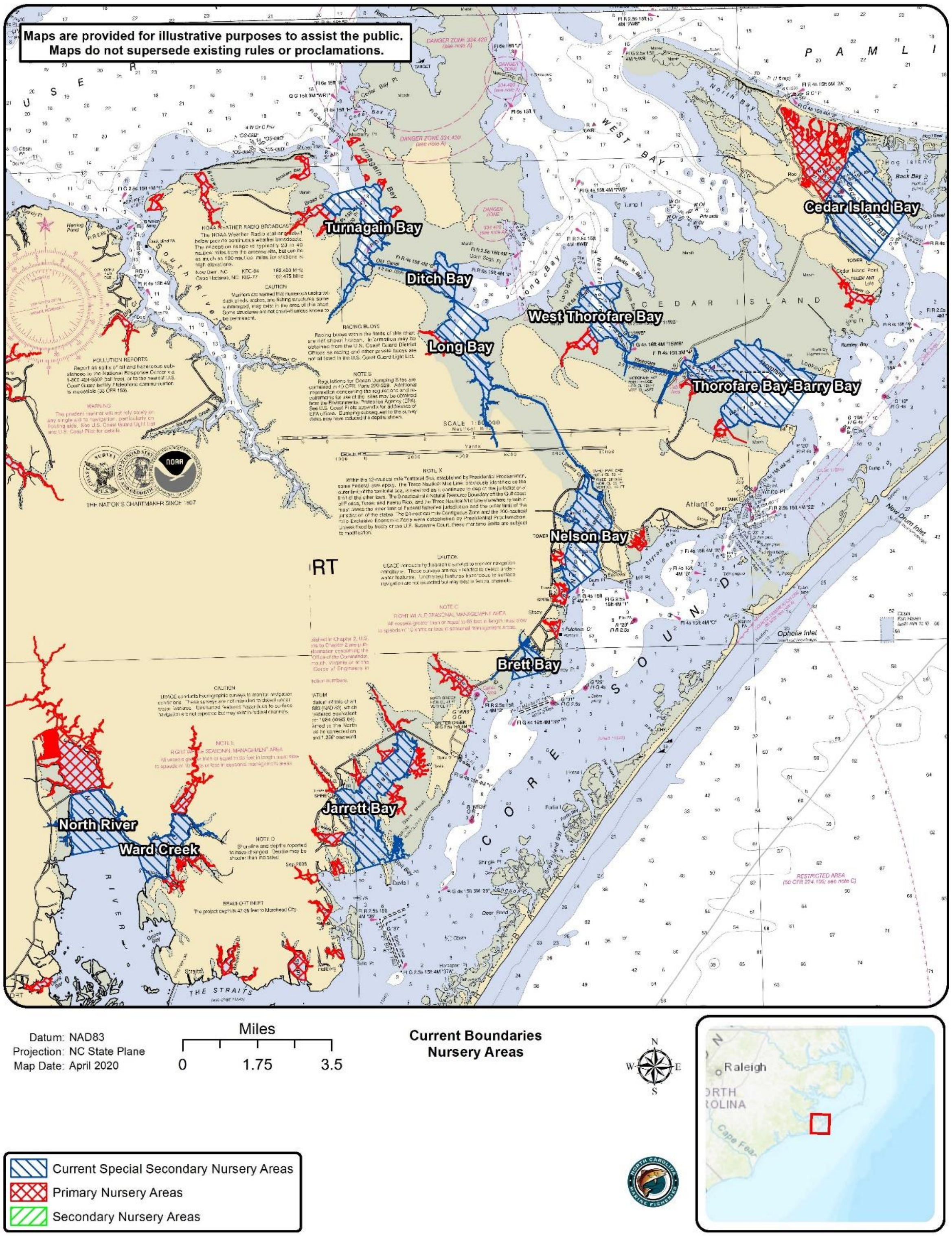


Figure 2.2.2. Map of the shrimp management and nursery areas in the Core Sound Region. Gill net attendance (<5 inch stretched mesh) will be required in all areas marked as special secondary nursery areas (SSNAs) from May 1 through November 30 if their designation is changed to permanent secondary nursery areas (SNAs).

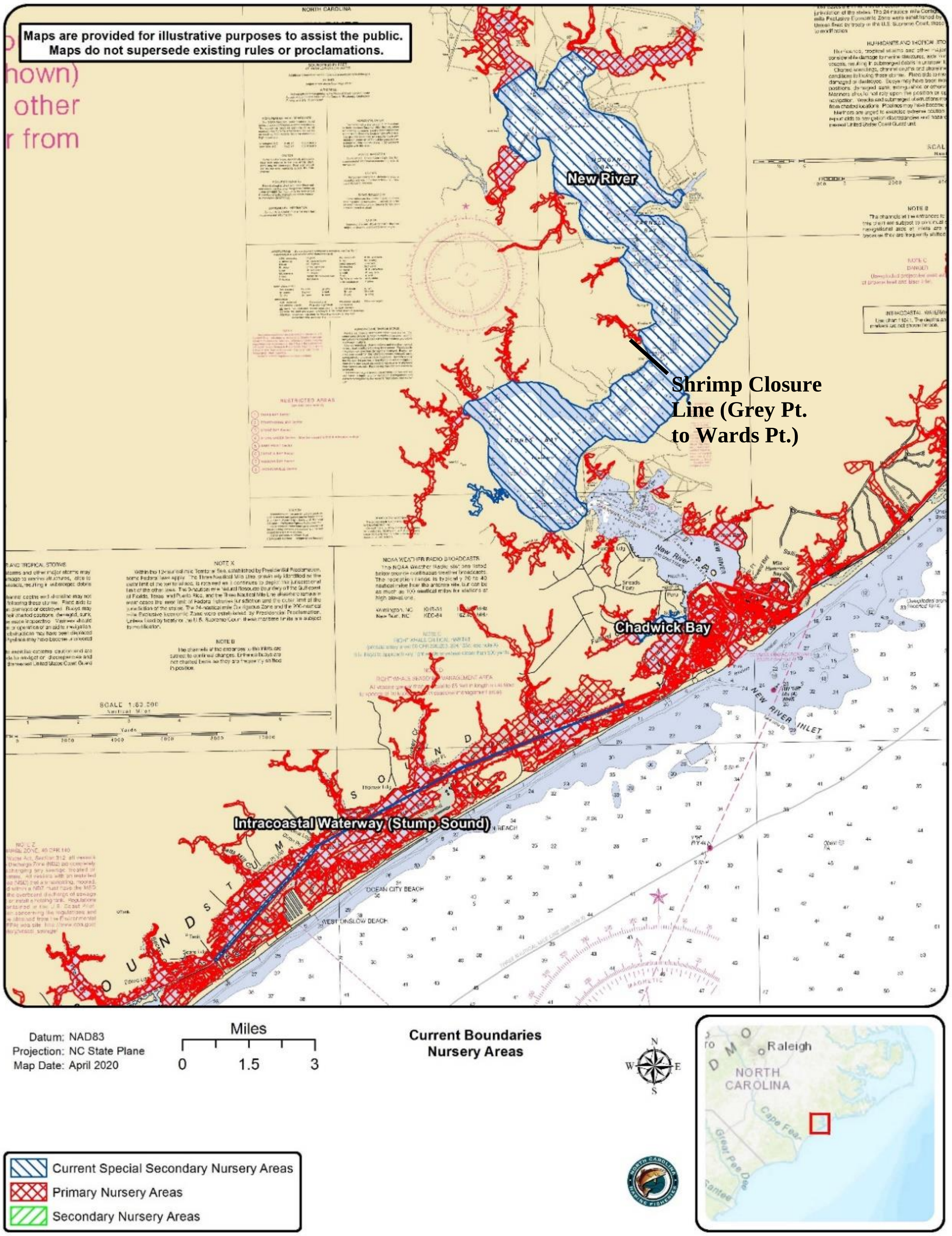


Figure 2.2.3. Map of the shrimp management and nursery areas in the New River, Chadwick Bay, and Stump Sound (IWW). Gill net attendance (<5 inch stretched mesh) will be required in all areas marked as special secondary nursery areas (SSNAs) from May 1 through November 30 if their designation is changed to permanent secondary nursery areas (SNAs).

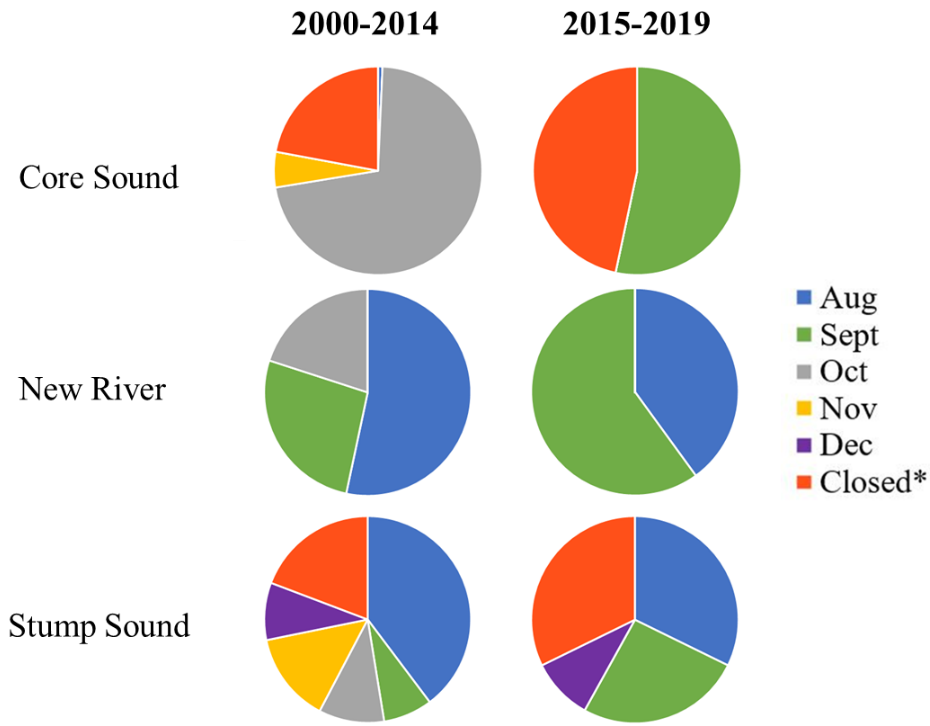


Figure 2.2.4. Special secondary nursery (SSNA) openings (percent of total) in Core Sound, New River, and Stump Sound shown by month and waterbody from 2000-2014 and 2015-2019. *Closures in Stump Sound may be partial closures.

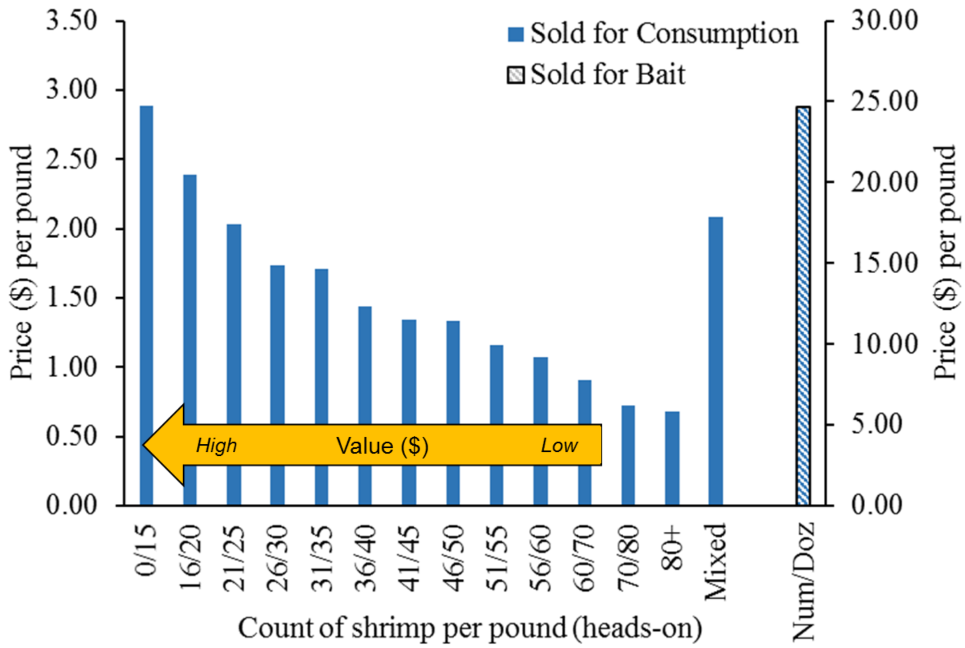


Figure 2.2.5. Value of estuarine shrimp by count size (heads-on), 1994-2019.

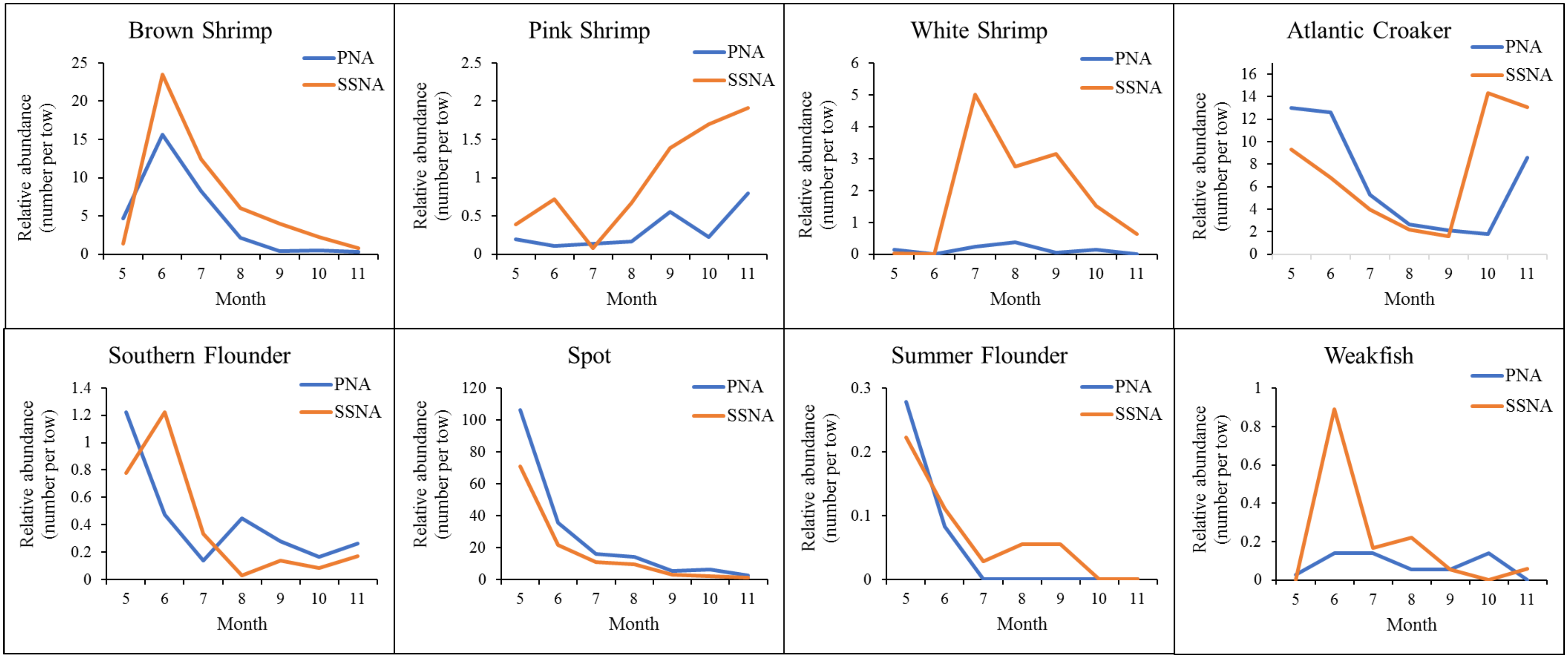


Figure 2.2.6. Relative abundance (number per sample) of target species collected in NCDMF Program 120 in Core (1978-1981) and Roanoke sounds (2006-2019) by nursery type (primary nursery - PNA, special secondary nursery - SSNA).

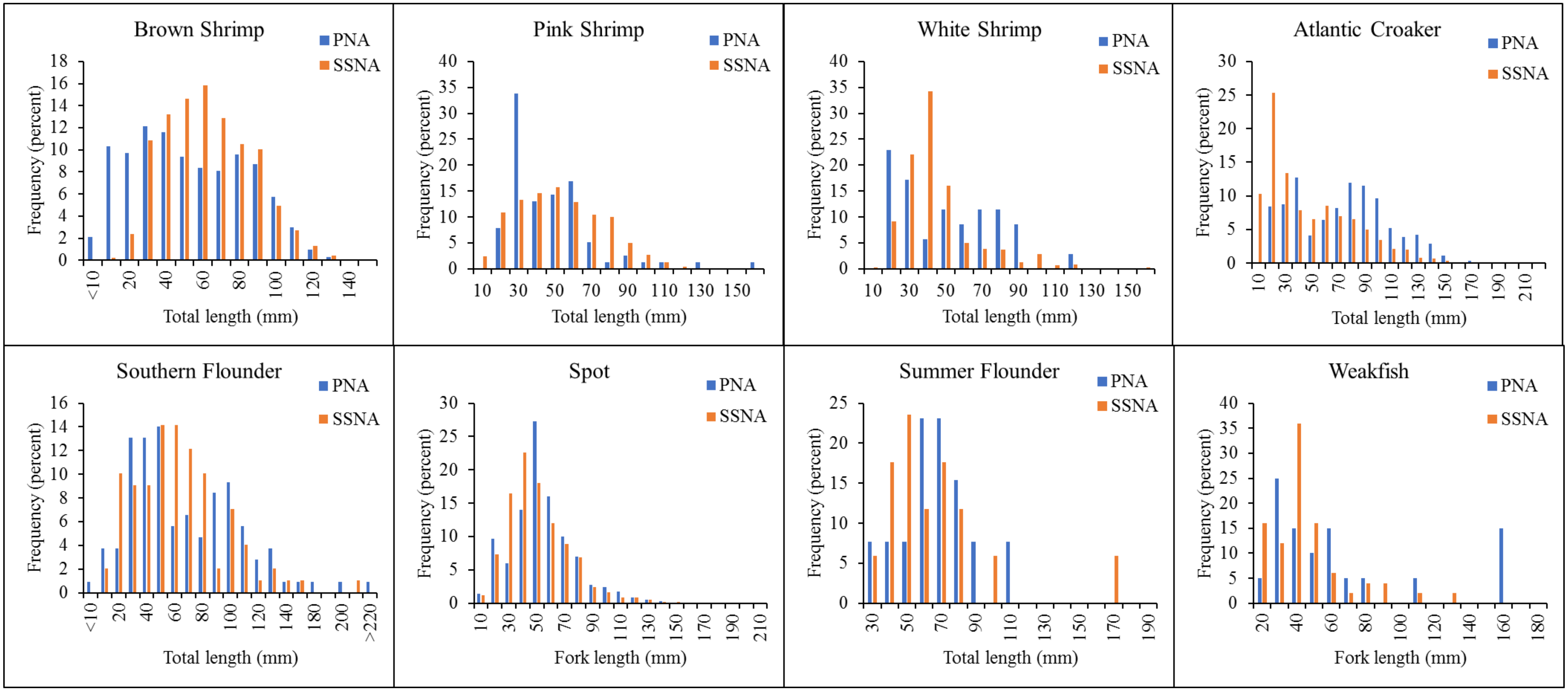


Figure 2.2.7. Expanded length frequency distribution of target species collected in NCDMF Program 120 in Core (1978-1981) and Roanoke sounds (2006-2019).

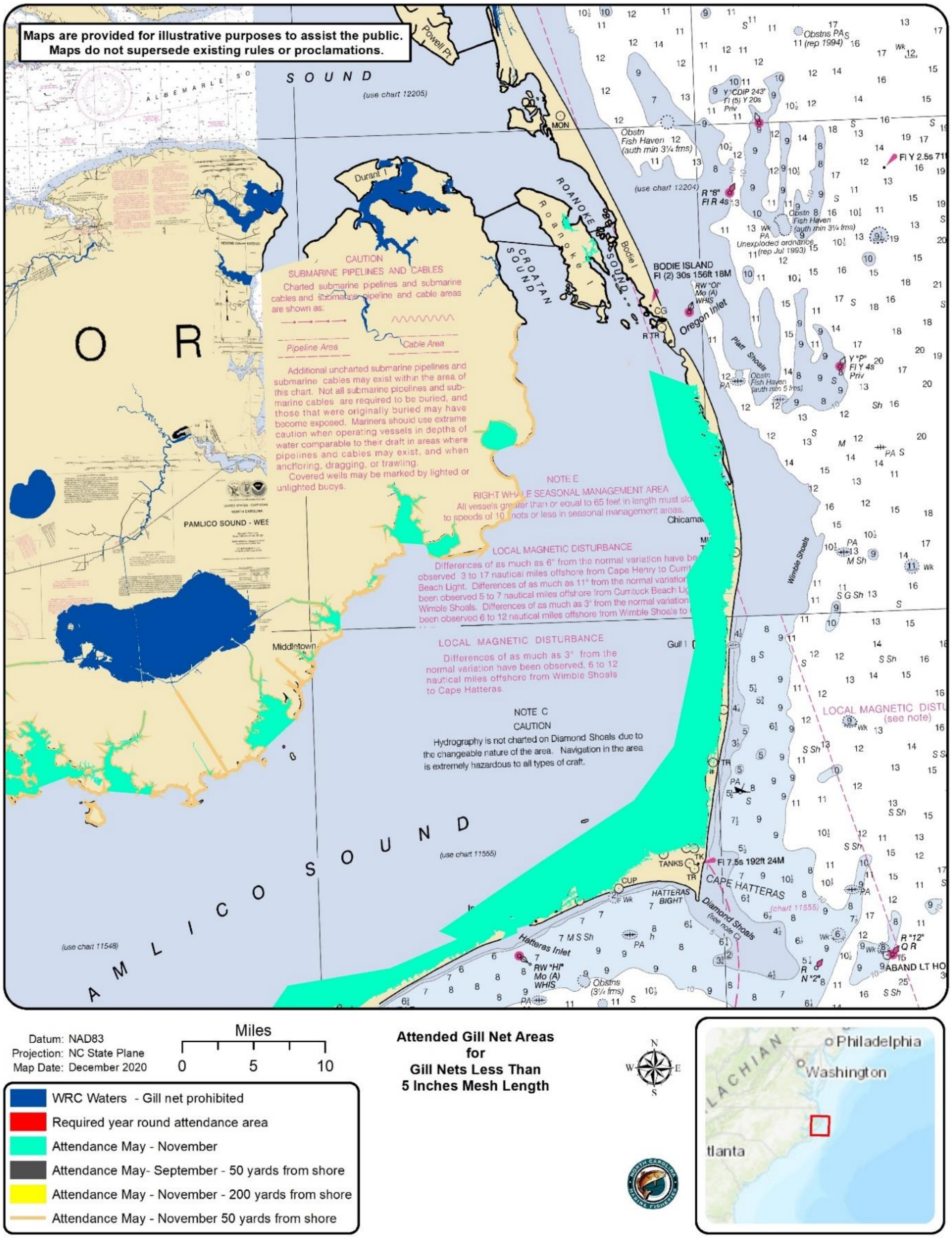


Figure 2.2.8. Map of current gill net attendance (<5 inch stretched mesh) and primary and permanent secondary nursery areas in Shallowbag, Kitty Hawk, and Buzzard bays.

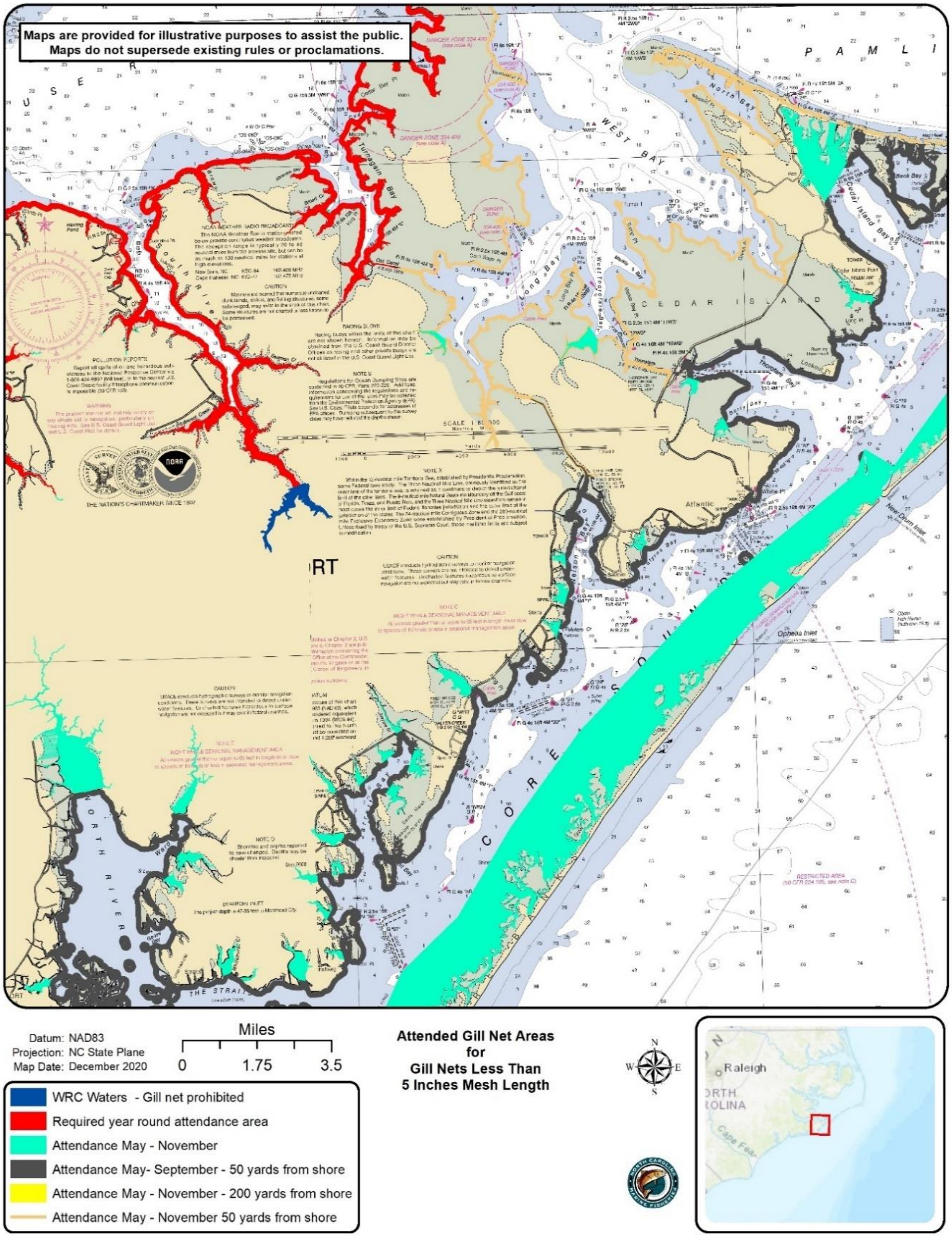


Figure 2.2.9. Map of current gill net attendance (<5 inch stretched mesh) and primary and permanent secondary nursery areas in West Thorofare, Long Bay-Ditch, Turnagain, Cedar Island, Thorofare-Barry, Nelson, Brett, Jarrett bays as well as North River and Ward Creek.

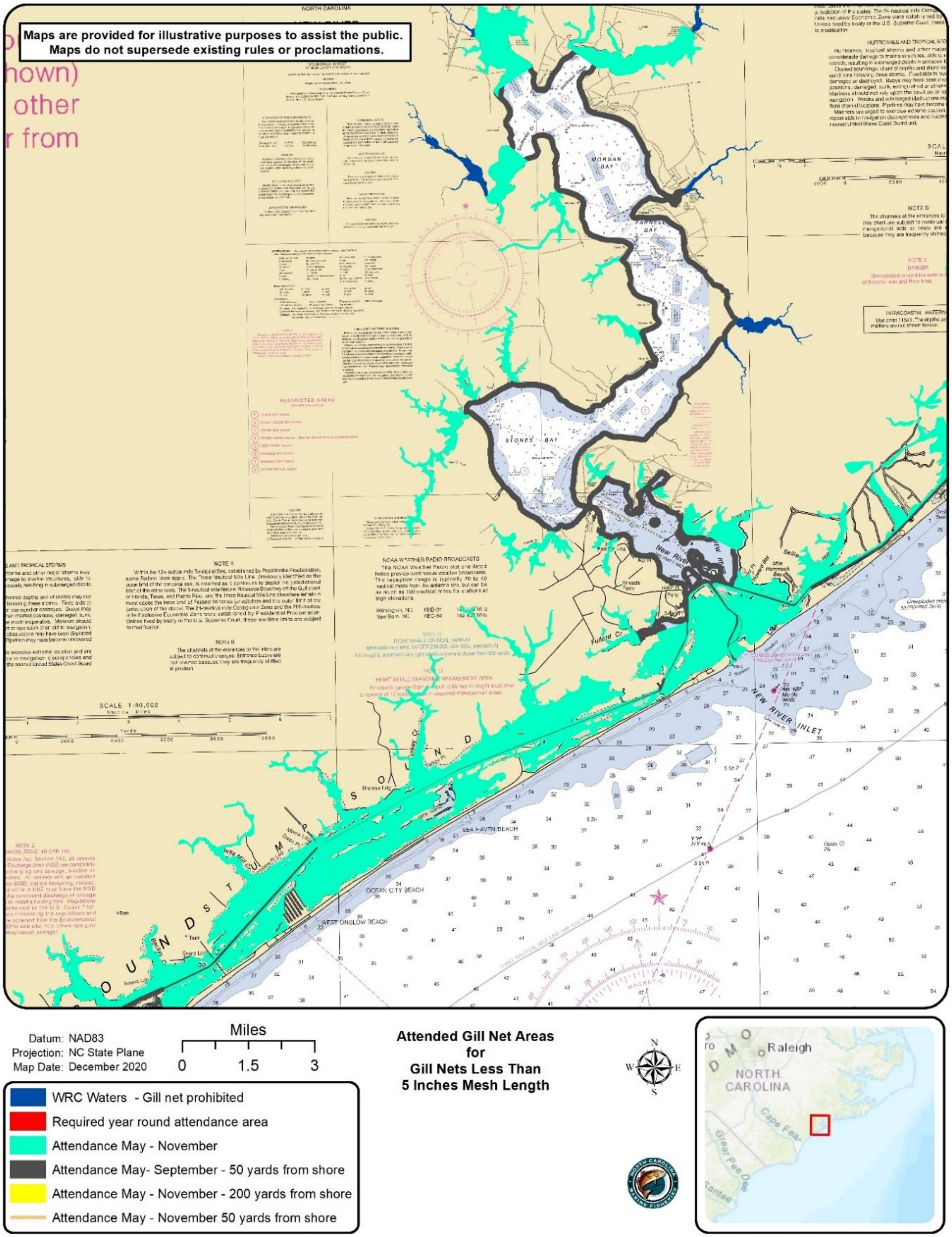
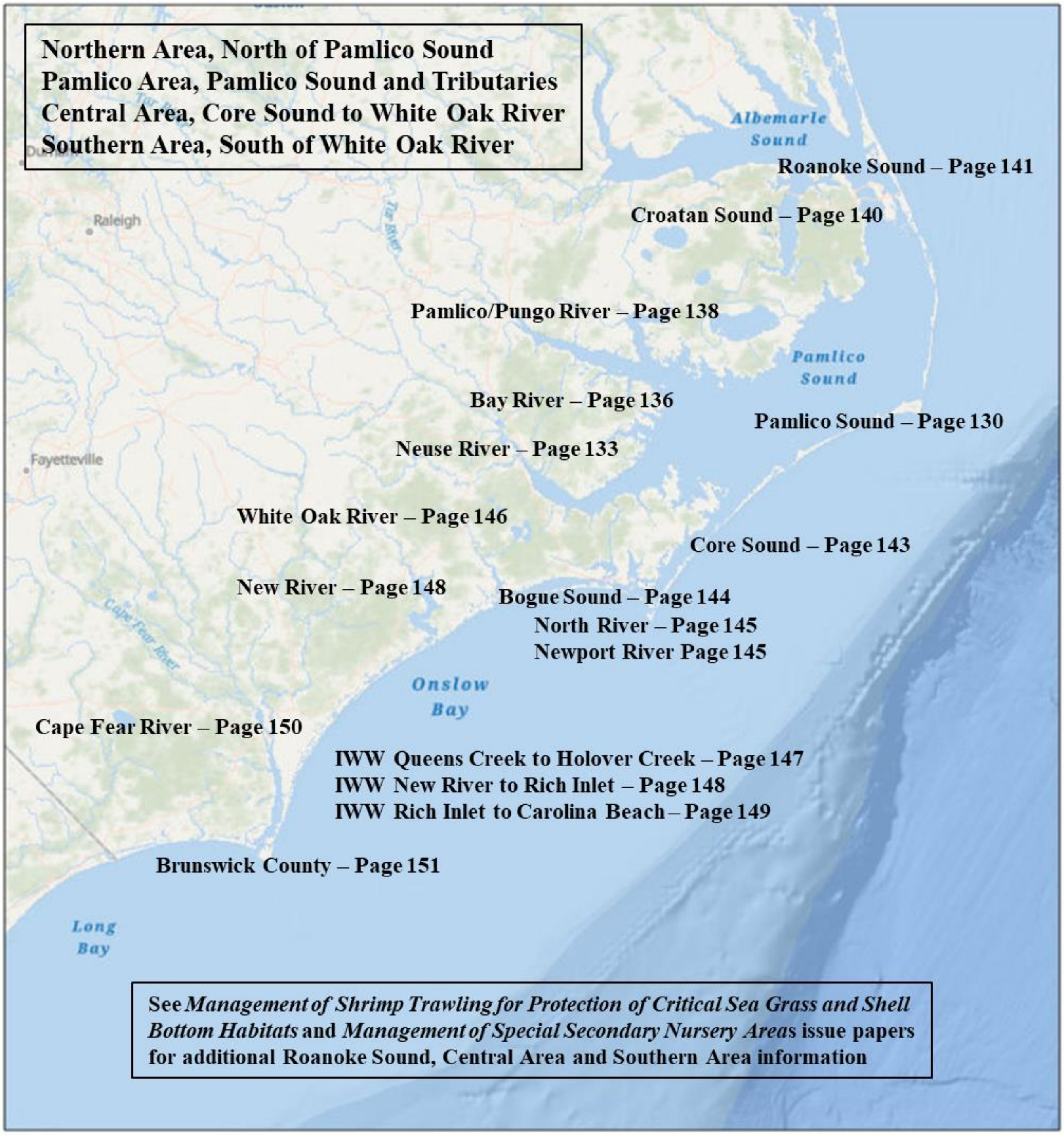


Figure 2.2.10. Map of current gill net attendance (<5 inch stretched mesh) and primary and permanent secondary nursery areas in New River, Chadwick Bay, Stump Sound (IWW).

APPENDIX 2.3. REDUCING SHRIMP TRAWL BYCATCH THROUGH AREA CLOSURES THAT INCREASE CONNECTIVITY BETWEEN CLOSED AREAS



I. ISSUE

Implementation of area closures in estuarine waters to increase connectivity between currently closed areas to further reduce shrimp trawl bycatch in North Carolina's Internal Coastal Waters.

II. ORIGINATION

The North Carolina Division of Marine Fisheries (NCDMF) Shrimp Plan Development Team (PDT).

III. BACKGROUND

The shrimp trawl fishery is one of the most economically valuable commercial fisheries in North Carolina and primarily targets brown (*Farfantepenaeus aztecus*), pink (*Farfantepenaeus duorarum*), and white (*Litopenaeus setiferus*) shrimp using otter trawls, skimmer trawls, channel nets, and other minor gears. From 1994 to 2019, commercial shrimp landings averaged 7,430,164 pounds and are highly variable for year to year (Table 2.3.1). While commercial landings are variable, the number of commercial trips and participants landing shrimp has generally declined since 2004. From 1994 to 2004, an average of 17,955 commercial trips landed shrimp and from 2005 to 2019, an average of 8,201 commercial trips landed shrimp. From 1994 to 2004 the average number of participants in the commercial shrimp fishery was 1,420, and from 2005 to 2019 the average number of participants was 746. From 1994 to 2004 an average of 7,130,582 pounds of shrimp were landed and from 2005 to 2019 and an average of 7,649,028 pounds of shrimp were landed. Static, or increased, average shrimp landings during periods of declining commercial shrimp trips and participants suggests increased efficiency of the shrimp fishery and/or increased abundance of shrimp. For further analysis of effort and shrimp trawl fleet characteristics, including trip days, see *Appendix 2.4: Managing Effort and Gear in the North Carolina Shrimp Fishery to Reduce Bycatch*.

The shrimp fishery is characterized as either estuarine (internal waters) or ocean. The estuarine fishery has accounted for 73% of the total commercial catch (Figure 2.3.1), 79% of the total commercial trips (Figure 2.3.2), and 81% of the participants (Figure 2.3.3) from 1994 to 2019 and generally accounts for over 50% of total landings each year. The Pamlico Region (Pamlico Sound, Pamlico/Pungo and Neuse rivers) has contributed over half of landings with minimal contributions coming from other regions from 1994 to 2019 (Figure 2.3.4). Despite minimal landings, the largest percentage of commercial trips landing shrimp occur in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River; Figure 2.3.4). The largest percentage of participants in the commercial fishery are in the Pamlico and Central regions.

From 1994 to 2019, the fishery has an average annual value of $16,071,856 with the Pamlico Region accounting for 59% of the value followed by the Atlantic Ocean at 28% (Figure 2.3.4). Since 1994, average annual value is $46,411 in the Northern Region, $9,572,987 in the Pamlico Region, $1,233,769 in the Central Region, $672,603 in the Southern Region, and $4,546,084 in the Atlantic Ocean.

Bycatch in the shrimp trawl fishery is a primary source of controversy due to concerns about the effects on populations of non-target species. For a review of trawl impacts on habitat see *Appendix: 2.1 Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats*. Though the impact of discarding bycatch, or incidentally captured non-target species, on fish populations is not well understood, the amount of dead discards in the shrimp trawl fishery is perceived by many stakeholders to influence the amount of resources available to recreational and other commercial fisheries. Economically valuable finfish species like Atlantic croaker (*Micropogonias undulatus*), southern flounder (*Paralichthys lethostigma*), summer flounder (*P. dentatus*), spot (*Leiostomus xanthurus*), and weakfish (*Cynoscion regalis*) are commonly caught as bycatch in the shrimp trawl fishery (Brown 2010) and are of particular interest in North Carolina because of their popularity and value as target species in recreational and commercial fisheries (NCDMF 2019).

Removals of these species as bycatch in the shrimp trawl fishery has been estimated and used in stock assessments for Atlantic croaker (ASMFC 2017a), spot (ASMFC 2017b), and southern flounder (Flowers et al. 2019). However, speculation persists that bycatch from shrimp trawls may be a strong contributing factor to poor stock status (e.g., weakfish and southern flounder) and perceived low abundance (e.g., Atlantic croaker and spot). Southern flounder is overfished and overfishing is occurring, though the southern flounder stock assessment found discards from shrimp trawls contribute minimally to fishing mortality (Flowers et al. 2019). Weakfish is depleted but the stock assessment found natural mortality accounts for a large portion of total mortality (ASMFC 2019). Subsequent work has found weakfish natural mortality consistently and substantially exceeds fishing mortality and high natural mortality occurs from fall to spring, coinciding with periods of emigration from estuaries and overwintering on the continental shelf (Krause et al. 2020a, 2020b). Stock status for Atlantic croaker and spot is unknown because neither stock assessment was approved for management use (ASMFC 2017a, 2017b). A Traffic Light Analysis (TLA), used to monitor the Atlantic croaker and spot stocks between stock assessments, indicates moderate concern for both species primarily because of coastwide declines in commercial and recreational landings and abundance declines in mid-Atlantic (New Jersey-Virginia) fishery-independent surveys (ASMFC 2020a; 2020b). The Atlantic States Marine Fisheries Commission (ASMFC) Sciaenid Management Board met in March 2021 to approve state implementation plans for Atlantic croaker and spot Addendum III management measures triggered by the TLA (50 fish recreational bag limit, 1% reduction in commercial landings; ASMFC 2020a, 2020b).

Existing management strategies have substantially reduced bycatch in the shrimp trawl fishery since the early 1990s, but shrimp trawls continue to capture sizeable numbers of non-target species (Brown 2010; see *Appendix 2.4: Managing Effort in the North Carolina Shrimp Trawl Fishery to Reduce Bycatch* for review of shrimp trawl bycatch studies). Throughout the entire southeast (North Carolina to Florida), billions of Atlantic croaker (ASMFC 2020a) and millions of spot (ASMFC 2020b) are discarded in the shrimp trawl fishery despite large declines in shrimp trawl effort (net hours fished) and overall bycatch since the early 1990s. Similarity of life history characteristics, size of individuals captured, and habitat use by shrimp and other common estuarine species increases the difficulty of achieving bycatch reductions in shrimp trawl fisheries. In addition, high abundance and pervasiveness of juvenile Atlantic croaker and spot (Table 2.3.2 and 2.3.3; NCDMF 2020a see sections for Atlantic croaker and spot; Paris et al. 2020a, 2020b), among other species, in North Carolina estuaries makes their capture as bycatch in shrimp trawls unavoidable in areas where shrimp trawling occurs. Though, use of turtle excluder devices (TEDs) and bycatch reduction devices (BRDs) has reduced bycatch in individual shrimp trawl tows (Brown et al. 2019).

Brown shrimp, pink shrimp, white shrimp, Atlantic croaker, southern flounder, summer flounder and spot spawn in the ocean during the fall and winter (Table 2.3.4). After hatching, larvae enter estuaries and settle into the upper portions of rivers, creeks, and bays. Weakfish spawn in estuaries and nearshore ocean habitats over an extended period from March through September and upon hatching, larvae disperse throughout the estuary. These species grow rapidly, moving out of shallow nearshore habitats into deeper open water habitats of lower estuaries as they grow.

This movement is evident when examining abundance and length-frequency data from the NCDMF Estuarine Trawl Survey (Program 120) and the Pamlico Sound Trawl Survey (Program 195; NCDMF 2020b, 2020c). Program 120 is conducted in nearshore creeks and bays during May and June while Program 195 occurs in Pamlico Sound and its major tributaries during June and September. For most species, abundance between the two surveys is positively correlated and length-frequency distributions show larger individuals are captured in Pamlico Sound than in adjacent smaller tributaries, suggesting movement.

While some species, like Atlantic croaker and spot are ubiquitous and can be found in diverse habitats, others like summer flounder and weakfish use a narrower range of habitat and are found primarily in higher salinity, deeper water areas (Paris et al. 2020a, 2020b). Just as shrimp become available to harvest by trawls as they grow and move from protected to open areas, non-target finfish species may become bycatch as they too grow and move.

Area restrictions are an effective management measure to meet sustainability objectives, reduce bycatch and protect vulnerable habitat (Fujioka 2006; O'Keefe et al. 2014; McConnaughey et al. 2019; Hilborn et al. 2020). In North Carolina, area restrictions have been implemented in coastal estuarine waters to protect important habitats, reduce bycatch, or reduce user group conflicts (Table 2.3.5; Appendix 3, Maps 3.1-3.12). For example, 161,831 acres of North Carolina's estuarine waters have been designated as Primary Nursery Area (PNA) or Secondary Nursery Area (SNA), primarily in the upper portions of estuarine rivers, creeks, and bays. Since the use of trawl nets is prohibited in nursery areas, these designations provide protection for juvenile shrimp and finfish during the early part of their life. Other areas where shrimp trawls are prohibited provide similar protections to bycatch species or important habitats.

IV. AUTHORITY

North Carolina General Statutes

§ 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

North Carolina Marine Fisheries Commission Rules
15A NCAC 03H .0103 Proclamations, General
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

- Section discusses estuarine areas where shrimp trawling occurs, characteristics of those areas and current shrimp trawl closures
- Management options are a starting point for discussion and are not recommendations
- Options are meant to illustrate concepts to increase connectivity between currently closed areas with the goal of reducing bycatch
- Options from adjacent areas must be considered in conjunction to accomplish increased connectivity
- The focus of this paper is area closures in Pamlico Sound and adjacent water bodies
- *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitat* and *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas* should be referenced for area closure options from Core Sound and south
- Amount of bycatch reduction from area closures is non-quantifiable (see *Appendix 1: Shrimp Trawl Bycatch Assessment*)
- Current and potential closures in the Atlantic Ocean are not discussed or considered

The acreage of area permanently or seasonally closed to trawling in North Carolina is extensive (approximately 1,216,163 acres; Table 2.3.5). Current closures represent a patchwork that in conjunction with other management measures (i.e., gear modifications, TEDs, BRDs), are likely effective in reducing bycatch at a local level. However, because shrimp and fish move throughout their life cycle and distributions in abundance change seasonally, daily, or even hourly, localized, fragmented area closures alone may be ineffective at reducing total bycatch (see *Appendix 2.4: Managing Effort and Gear Modifications in the North Carolina Shrimp Fishery to Reduce Bycatch* for further discussion of area and bycatch). If the goal of implementing additional area restrictions is to reduce bycatch, the objective should be increasing connectivity between currently closed areas to better encompass the life cycle and distribution of common bycatch species.

Seasonal Closures

Time and area closures are an effective management tool for achieving sustainability goals and reducing bycatch (O’Keefe et al. 2014; Hoos et al. 2019; Hilborn et al. 2020) and have been implemented in the North Carolina shrimp trawl fishery to reduce bycatch, delay harvest of shrimp (see *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas* issue paper), and reduce conflict between fishing sectors. For example, Special Secondary Nursery Areas (SSNA) can only be opened to shrimp trawling by proclamation from August 16 to May 14 and timing of openings corresponds to periods when shrimp are larger and the abundance of bycatch species is reduced. Seasonal area closures may be effective in reducing bycatch, while continuing to allow access to the shrimp resource and could be considered as a component of any area closure considered for implementation.

Under existing regulations in Pamlico Sound shrimp trawlers can choose when to fish except in areas with existing restrictions (i.e., PNAs, SNAs, shrimp trawl net prohibited areas, etc.). An option that has been suggested is to open the sound when shrimp count (number of shrimp per pound heads-on) reaches a desired size, similar to how SSNAs are managed (see *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas*) which could delay shrimp harvest and reduce bycatch. However, because of variable openings this strategy may not delay shrimp harvest or reduce bycatch. For example, analysis of Trip Ticket data indicates that a 60-count opening target size for Pamlico Sound (as proposed in a 2016 petition for rulemaking) may not provide a predictable outcome in delaying the opening of shrimp season (NCDEQ 2019). Shrimp landings (by count size) in Pamlico Sound indicate that the shrimping season may not close if a 60-count opening target size is established and shrimp species is not accounted for. Roughly 90% or greater of all shrimp (brown, white, pink) harvested in Pamlico Sound are 60 count or lower (larger shrimp have lower count sizes). A minimal delay in the opening date would occur if a 60-count opening target size were to include species-specific openings. By May, 52% of all brown shrimp landed in Pamlico Sound from 1994 to 2015 were 56/60 count or lower, and by June, 95 percent were 56/60 count or lower. The same count size of white shrimp landed ranged from a low of 87% in June to a high of 100% in January. By April, 95% of the pink shrimp landed from Pamlico Sound were 56/60 count or lower.

Enacting a closure until shrimp count size reaches 60 shrimp per pound in Pamlico Sound could also result in “grand openings,” where many vessels operate in an area following a closure. Reductions in bycatch may be negated by recoupment from the increased effort once an area is opened. Previous fishing seasons observed by NCDMF have shown that delayed openings in SSNAs, like those in New River and Stump Sound, have resulted in many vessels in a small area trying to recoup harvest and effort once the areas are opened. Additionally, early season openings could occur if environmental conditions are favorable; thus, count sizes may not be an effective means of reducing bycatch. Setting a static season, with set opening and closing dates may be a more appropriate strategy to achieve bycatch reductions.

Gear Exemptions

Allowing continued use of gears with less bycatch concern could be considered for any areas closed to shrimp trawling (see NCDMF 2015 for review of gear types including, characteristics, limitations, and bycatch concerns). For example, since 2010 it has been unlawful to use trawl nets, except skimmer trawls, upstream of the Highway 172 Bridge in New River (NCDMF 2006; Rule 15A NCAC 03J .0208). The benefits of skimmer trawls include reduction of finfish bycatch, less bottom disturbance, less fuel consumption, more effective fishing time, and less culling time (Coale et al. 1994; Ruderhausen and Weeks 1999; Scott-Denton et al. 2006). In addition, skimmer trawl tailbags can be hauled back more frequently allowing for increased survival of bycatch. However, skimmer trawls are less effective for brown or pink shrimp (Coale et al. 1994) and can only be used over bottom that is free from obstructions and perform best in shallow water. If additional areas are closed to shrimp trawling, use of other gear types whose use has less bycatch concerns, like skimmer trawls, could be allowed to continue harvesting shrimp.

Fishery Impacts

Any additional shrimp trawl area closures would reduce access to the shrimp resource by the commercial and recreational sectors resulting in economic impacts to the shrimp fishery and those operating and working on shrimp trawlers. Reduced effort resulting from area closures will likely reduce the efficiency of the shrimp trawl fishery and consequently reduce the amount of shrimp harvested and likewise profitability of each trip. This may also lead to reduced employment in the shrimp trawl fishery as operators have to deal with tighter profit margins. However, there is also the possibility for economic gains in other portions of the shrimp fishery as well as other fisheries. Additional opportunities for recreational and commercial fishermen using non-trawl gears may lead to some economic gains for commercial fishermen using these gears and recreational fishery suppliers as fishermen purchase additional gear. Another potential benefit of reduced shrimp trawl effort in closed areas may be improved habitat and reduced bycatch mortality (hence increased survival) of bycatch and other species and thus have more available for harvest as recruits grow into other fisheries (both commercially and recreationally). Additionally, improved habitat may improve other economic niches like eco-tourism. Although, these types of economic benefits are more abstract, uncertain, and dependent on other external factors.

Closures in nearshore waters or smaller waterbodies would be particularly detrimental to smaller commercial boats and the recreational sector. Though brown shrimp and white shrimp can be caught throughout the summer, brown shrimp are generally available to the fishery earlier and the white shrimp fishery primarily occurs in the late summer and fall (NCDMF 2015). As the brown shrimp fishery has declined in some areas of the state, brown shrimp landings in others, like Pamlico Sound and Neuse River, have remained consistent or increased allowing the fishery to meet market demands for shrimp throughout the summer. Many areas that might be considered for closure are important to the early season brown shrimp fishery and may disproportionately impact participants in this fishery.

If additional area closures occur in locations with high shrimp abundance, shrimp trawling efficiency may be affected, leading to increased effort and higher bycatch. For example, nearshore creeks and bays can act as a bottleneck, concentrating shrimp as they move out of these areas making them easier to capture in high volumes with less effort. Closing these areas creates additional area for shrimp to disperse and spread out into larger waterbodies. Increased dispersal may make shrimp more difficult to capture which could increase effort in open areas and consequently increase bycatch. If additional areas are closed, shrimp trawl effort may shift to open areas where bycatch would still occur. Concentrating effort in small areas could lead to localized depletion of shrimp and bycatch species and may have negative impacts to habitat (see *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom)*. In addition, if remaining open areas are unproductive for shrimp, the shrimp trawling industry would experience additional negative impacts.

Quantifying Benefits

The expected amount of bycatch reduction from any additional area closures is unquantifiable and the population level benefits to species like Atlantic croaker, spot, southern flounder, summer flounder, and weakfish are impossible to predict due to confounding factors like natural mortality and offshore migration. The objective of additional area closures would be to create connectivity between closed areas to better encompass the life cycle of common bycatch species more completely because once they enter open estuarine waters or the ocean they become less susceptible to shrimp trawls because of the increased area for dispersal.

Measuring the success of area closures implemented to reduce bycatch is difficult. At the population level, the method for gauging success is a stock assessment. Atlantic croaker, spot, southern flounder, summer flounder and weakfish are interjurisdictional stocks managed and assessed by regional commissions and councils. For example, Atlantic croaker is managed and assessed as a single population from the Atlantic coast of Florida through New Jersey (ASMFC 2011). Atlantic croaker spawn in the ocean, larvae are transported inshore, and juveniles settle in coastal nurseries. Upon emigrating from North Carolina waters, Atlantic croaker contribute to the coastwide stock. The objective of reducing bycatch of juvenile Atlantic croaker in North Carolina waters would be to increase the coastwide population. However, population level benefits may not be realized if significant mortality (fishing or natural) occurs elsewhere along the coast or at different life stages (e.g., larval or adult). If bycatch is reduced through shrimp trawl area closures in North Carolina waters and stock assessments do not indicate increases in population size, that does not mean management measures have failed, rather it suggests these are dynamic stocks whose population is influenced by complex natural and anthropogenic factors. In contrast, if stock assessments indicate increases in population size it would be difficult to credit management measures in North Carolina because of the other influences on these stocks. For management measures in North Carolina waters to significantly increase the coastwide population of any of these species, juveniles residing in North Carolina would need to contribute a significantly larger portion to the stock than other areas. Data needed to evaluate the contribution of North Carolina waters to coastwide stocks does not exist and would be difficult to obtain.

One method that could be used to gauge success of management measures is fishery independent surveys. The Pamlico Sound Survey (Program 195; NCDMF 2020b) and the Independent Gill Net Survey (P915; NCDMF 2020d, 2020e) provide indices of relative abundance for important commercial recreational finfish species including Atlantic croaker, spot, southern flounder, and weakfish. While the Pamlico Sound Survey primarily samples juveniles, the survey provides an annual index of abundance for age-1 and older spot (ASMFC 2020b). The independent gill net survey provides indices of adult abundance that are evaluated annually for many North Carolina species (NCDMF 2020a). Evaluating long term trends in adult abundance, length frequency, and age structure from these surveys is the most direct and immediate method for inferring success of any area closures.

Fishery independent surveys are not equivalent to stock assessments and increasing or decreasing trends in abundance cannot be extrapolated to the population level for interjurisdictional species. Fishery independent surveys do provide invaluable information about species abundance in North Carolina waters and what might be available to recreational and commercial fisheries. Increasing abundance and expanding age structure of adult fish could indicate management measures to reduce bycatch are successful in allowing increased survival of juvenile fish to older ages making them available to fisheries in North Carolina waters. However, decreasing, or neutral trends in abundance are not necessarily indicative of a failure to reduce bycatch. As noted, these species have complex life cycles with many confounding factors influencing recruitment and abundance.

Since all of these species spend at least part of their life in the Atlantic Ocean, inshore fishery independent surveys may not detect increases in abundance and the expected benefits of reducing bycatch to North Carolina inshore fisheries may never be realized.

Area Closure Examples

Bycatch in the North Carolina shrimp trawl fishery has been reduced but still occurs at a high level. However, the degree to which shrimp trawl bycatch impacts fish stocks at the population level is either unknown or thought be minimal. Given inconclusive information about the adverse effects of shrimp trawl bycatch on fish populations, a balanced approach to area closures considering areas where shrimp trawling occurs, distribution and life history of common bycatch species and economic impact should be considered. Similar approaches have been proposed for habitat protection. Fujioka (2006) recommended a balanced approach to area closures and suggested closing large amounts or lightly fished areas and small amounts of heavily fished areas to protect habitat and maintain catch. While this specific example may not effectively reduce bycatch, similar balanced approaches may work.

The following issue paper sections discuss estuarine areas where shrimp trawling occurs, characteristics of those areas, and existing closed areas. The management options presented in this paper are a starting point for discussion of shrimp trawl area closures to limit or reduce bycatch. The options illustrate concepts for area closures that could be implemented **to increase connectivity between closed areas with the goal of reducing overall bycatch.** Public input could provide additional options.

Because of the disparity in shrimp landings and fishing effort between estuarine waters and the ocean (Figures 2.3.1; 2.3.2; 2.3.3), available data and the ecological concepts being considered, the focus of this issue paper is estuarine waters. North Carolina's coastline on the Atlantic Ocean is comprised of barrier islands that stretch approximately 300 miles. Shoals extending perpendicular from shore accompany capes and inlets along the coastal ocean. Nearshore hard bottom areas, dense concentrations of marine algae, artificial reefs and shipwrecks limit the amount of trawlable bottom available. Of North Carolina's 726,007 acres of Atlantic Ocean waters 138,561 acres are closed to shrimp trawling, 4,752 acres are managed, and 582,694 acres are open. In the Atlantic Ocean off Brunswick County, it is unlawful to use shrimp trawls from 9:00 pm to 5:00 am each day, because studies have shown bycatch in this area is higher at night than during the day (Ingraham 2003).

The division does not conduct any fishery independent sampling in the Atlantic Ocean that could be used to determine the distribution of fish and inform management options. The South Carolina Department of Natural Resources conducts the SEAMAP-SA Coastal Survey which occurs in the coastal zone of the South Atlantic Bight from Cape Hatteras, North Carolina to Cape Canaveral Florida. The Virginia Institute of Marine Science conducts the NEAMAP Mid Atlantic survey which occurs from Cape Cod Massachusetts to Cape Hatteras North Carolina. The distribution of sampling effort in the coastal ocean surveys may not be sufficient to adequately represent species distribution at a scale fine enough to inform area closures in North Carolina coastal waters. In addition, because North Carolina only has jurisdiction within three miles of shore, which represents a small portion of most species Atlantic Ocean range, any closures are likely to be minimally effective in reducing bycatch.

<u>Pamlico Area (Pamlico Sound, Neuse River, Bay River, Pamlico/Pungo River)</u>

PAMLICO SOUND

The sound is divided into two basins east and west of Bluff Shoal. Most feeder creeks and bays are classified as PNA, SNA, SSNA, or no trawl areas. Along the Hyde County shoreline all bays and tributaries are closed to trawling except for West Bluff Bay, East Bluff Bay, Parched Corn Bay, and Sandy Bay (Appendix 3, Maps 3.1-3.3). There are no other area restrictions related to shrimp trawling along the Hyde County shoreline of Pamlico Sound.

Along the eastern side of Pamlico Sound, no trawling is allowed in an area described in rule 15A NCAC 03R .0106 (1) to protect sea grass beds (Appendix 3, Maps 3.1-3.3), though the Fisheries Director may, by proclamation, open this area to peeler crab trawling (Rule 15A NCAC 03J .0104 (4)). In crab spawning sanctuaries designated at Oregon, Hatteras, Ocracoke, and Drum inlets, it is unlawful to use trawls from March 1 to August 31. Trawling is also prohibited in three Military Danger Zone and Restricted areas located southeast of the mouth of Long Shoal River, east of the mouth of Bay River, and near Piney Island including Point of Marsh and Newstump Point. Along the southern shore, parts of West Bay can be opened to trawling by proclamation.

Since 1994, the Pamlico Sound has accounted for 56% of total commercial shrimp landings in North Carolina and within the Pamlico Region (Pamlico Sound, Bay River, Pamlico/Pungo River), the sound has accounted for 96.1% of shrimp landings (Table 2.3.6), 81.6% of the trips and 73.9% of the participants from 1994 to 2019 (Table 2.3.7). Within the Pamlico Region, the Pamlico Sound has accounted for 96.5% of the value (Figure 2.3.5). Shrimp landings and trips have fluctuated since 1994 and after declining from 1994 to 2005, have generally increased or remained consistent. Shrimp landings from 2015 to 2018 were amongst the highest recorded and landings in 2017 were the highest in the time series. High landings during these years occurred without substantial increases in trips. Historically, brown shrimp have been the primary species caught in the Pamlico Sound with lesser numbers of white and pink shrimp landed. However, since 2011 white shrimp landings have increased and in 2017 white shrimp comprised most of the landings.

Management Considerations for Pamlico Sound

The Pamlico Sound is an important habitat for many fish species and is used extensively as juvenile habitat for estuarine dependent species like Atlantic croaker, spot, southern flounder, summer flounder and weakfish. Atlantic croaker and spot are amongst the most abundant finfish species and are generally ubiquitous throughout the sound (Table 2.3.3; Paris et al. 2020a, 2020b). While trawl closures are designated in most bays and tributaries of the sound and along the eastern shore, most of the sound is open to trawling. Because of the extent to which some species use the sound, additional isolated closures would be unlikely to substantially reduce bycatch. Any additional area closures should aspire to create linkages between habitats currently closed to trawling. Achieving this objective would create a network of areas where juvenile fish and crustaceans could move between nursery areas, open sound habitats, and adult habitat in the ocean. While most of the sound has soft, muddy, or sandy bottom that is more resilient to damage from shrimp trawls (see *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* for review of trawl impacts on habitat), additional closures could help minimize bottom disturbance and decrease periods of turbidity further aiding survival and growth of estuarine dependent species.

Closing the entire Pamlico Sound to shrimp trawling would be a severe management measure, essentially eliminating half of the multi-million-dollar shrimp fishing industry in North Carolina. While a complete closure would reduce bycatch, the goal and benefits would be uncertain given current abundance, stock status, and life history characteristics of most species of concern (i.e., Atlantic croaker, spot, weakfish). More refined area closures implemented with the objective of linking areas already closed to trawling may be effective in reducing bycatch without severe impacts to the shrimp fishing industry that would occur with a complete closure.

Despite high abundance and non-specific habitat use by some estuarine dependent species, shrimp and juvenile fish are not uniformly distributed throughout the sound. Some areas exhibit consistently higher abundance and are termed clusters or “hot spots”. Identification of abundance hot spots in Pamlico Sound, in combination with life history information can inform designations of more refined area closures that could achieve bycatch reductions.

The Pamlico Sound Trawl Survey (Program 195) is conducted by NCDMF in Pamlico Sound and its tributaries during June and September and has run continuously since 1987. The primary objective of Program 195 is to produce fishery independent indices of abundance for important recreational and commercial fish species. The survey uses a stratified random design with strata designated by geographic location and water depth. Stations (one minute by one-minute grid system equivalent to one square nautical mile) are randomly selected, with 54 stations sampled in June and 54 stations sampled in September (108 total annually; see NCDMF 2019b; Paris et al. 2020a, 2020b for detailed survey methodology).

To identify hot spots, abundance at survey sites falling within a predetermined distance are compared to each other. When abundance is high at a site, and the site is surrounded by other sites with high abundance they are labeled high-high clusters, indicating that area is likely a hot spot for a species. Sites with low abundance that are surrounded by other low abundance sites are labeled low-low clusters, indicating the area is likely not a hot spot for a species. Sites with low abundance surrounded by sites with high abundance are labeled low-high clusters indicating that the overall area may be a hot spot, but the individual site had lower catch abundance compared to the surrounding sites. Sites with high abundance surrounded by sites with low abundance are labeled high-low clusters indicating that while the overall area may not be a hot spot, the individual site had higher catch abundance compared to the surrounding sites. See *Appendix 2.3.A: Hot Spot Analysis* for further description of hot spot analysis methodology.

Hot spots of abundance in Pamlico Sound during June and September were identified for Atlantic croaker, spot, weakfish, southern flounder, summer flounder, brown shrimp, white shrimp, and pink shrimp (Figures 2.3.6-2.3.13; Appendix 2.3.B, Maps 2.3.B.1-2.3.B.16); for aggregate finfish (Atlantic croaker, spot, southern flounder, summer flounder, and weakfish; Figure 2.3.14); and shrimp (white shrimp, brown shrimp, and pink shrimp; Figure 2.3.15).

Distribution of hot spots varies by species and season. Atlantic croaker hot spots are distributed throughout the sound but are clustered closer to the Hyde County shoreline in September compared to June (Figure 2.3.6). Spot hot spots show a distinct seasonal shift from the center of the sound in June to near the mouth of the Pamlico and Neuse rivers in September (Figure 2.3.7). Southern flounder hot spots are distributed throughout the western Pamlico Sound with hot spots in June clustered near the mouth of the Neuse River and hot spots in September clustered near the mouth of the Pamlico River (Figure 2.3.8). Summer flounder hot spots are concentrated in the northern Pamlico Sound and Croatan Sound in June and September (Figure 2.3.9). Weakfish hot spots are concentrated in the center of Pamlico Sound and are more widespread in June compared to September (Figure 2.3.10).

White shrimp hot spots are more prevalent in September than in June and are concentrated in the center of the sound in June and closer to shore in September (Figure 2.3.11). Brown shrimp hot spots are located close to shore in June and more toward the center of the sound in September (Figure 2.3.12). Pink shrimp hot spots are more prevalent in September than June and are concentrated in the center of the sound (Figure 2.3.13).

Because of the disparity in hot spot distribution between species and seasons (Figures 2.3.14-2.3.15), no single area closure encompasses the range of all species, except for a complete closure. However, because of patterns in hot spot distribution and known life history characteristics, certain area closure configurations could be implemented to create linkages between closed areas, encompass hot spots, and allow for movement of fish species, while continuing to allow access to shrimp. Creating an area closure linking the bays and tributaries with other closed areas and coastal inlets may be an effective measure to reduce bycatch.

Most common bycatch species (i.e., Atlantic croaker, spot) use nursery areas located in estuarine bays and creeks before moving into the open sound and eventually through coastal inlets into the ocean. Creating a no shrimp trawling buffer area along the northern/western shore of Pamlico Sound would create a link between nursery areas and coastal inlets, with larger area closures encompassing the distribution of more species and creating greater linkages (Figure 2.3.16; Table 2.3.8). Essentially, this strategy provides greater area for fish and shrimp to disperse as they leave nursery areas along the northern/western shore of Pamlico Sound which lessens the likelihood of being caught in shrimp trawls. In addition, this type of closure protects habitats near the mouths of the Neuse, Bay and Pamlico river and in Croatan and Roanoke sounds.

Because distribution of fish and shrimp shifts seasonally this option could be implemented seasonally, or a seasonal extension could be added to incorporate additional important habitats (Figure 2.3.17). Early season closures may not effectively reduce bycatch because shrimp and fish have not started to move from nursery areas, and shrimp trawl effort is low. Later season area closures, like August 1 through November 30, may be effective in reducing bycatch because shrimp and fish have moved into open water habitats and shrimp trawl effort is higher. For example, weakfish hot spots have been identified in the area east of Bluff Shoal in central Pamlico Sound (Figure 2.3.10; Appendix 2.3.B, Maps 2.3.B.9-2.3.B.10). Incorporating this area as a seasonal closure would reduce bycatch of weakfish locally, while accommodating movement throughout the season.

Example Options for Pamlico Sound

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

1. *Status Quo* – No additional area or seasonal closures
   + Continues to allow access to the shrimp resource in Pamlico Sound
   + No impact to shrimp trawling industry
   + Bycatch reductions may still be achieved through other strategies (i.e., gear modifications)
   - No additional bycatch reductions from area closures
   - Continued conflict between trawlers and other sectors

2. Create no shrimp trawl buffer with seasonal extension (Figure 2.3.17)
   + Continues to allow access to the shrimp resource in most of Pamlico Sound
   + Buffer closures in combination with other strategies (i.e., gear modifications) may reduce bycatch
   + Reduces some conflict between trawlers and other sectors
   + Creates connectivity between other closed areas
   + Habitat protections
   - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
   - May increase trawl effort in open areas
   - May not reduce bycatch if size of closed area is not sufficient to account for movement of fish

3. Complete closure
   + Reduces bycatch
   + Reduces conflict between trawlers and other sectors
   + Creates increased area for juvenile fish to disperse into larger water bodies
   + Habitat protections
   - Eliminates access to shrimp resource is areas that are very productive for shrimp harvest
   - May increase trawl effort in open areas
   - Would create economic hardship

NEUSE RIVER

Within the Neuse River shrimp are generally only found as far upstream as Slocum Creek. From 1994 to 2019, the Neuse River accounted for 3.2% of shrimp landings in the Pamlico area (Pamlico Sound, Bay River, Pamlico/Pungo River; Table 2.3.6), 15.8% of the trips, and 18.2% of participants (Table 2.3.7). Within the Pamlico Region, the Neuse River has accounted for 2.8% of the value (Figure 2.3.5). There has been little trend in landings or trips since 1994. Brown shrimp are the primary species caught in the Neuse River with lesser numbers of white shrimp and very few pink shrimp landed.

Shrimp trawling is prohibited upstream of a line from the Minnesott Beach Ferry running south to a point at the Cherry Branch Ferry (Appendix 3, Map 3.3). This closure was implemented through the 2006 shrimp FMP based on management recommendations from the 2005 Southern Flounder FMP to address the issue of sublegal southern flounder discards in the shrimp trawl fishery (NCDMF 2006). Most Neuse River tributaries are designated as nursery area, but trawling is allowed in parts of Clubfoot Creek, Adams Creek, South River and Turnagain Bay. Only small portions of Clubfoot Creek are open to trawling and most effort is by smaller commercial boats. Trawling activity in Adams Creek is from a mix of small to mid-size commercial and recreational trawlers. South River and Turnagain Bay receive mostly commercial trawling activity but effort in South River has declined recently and Turnagain Bay is not a significant area to the shrimp trawl fishery. Within areas of the Neuse River and its tributaries that are open to trawling, there is a prohibition on trawling in water depths less than six feet from June 1 through November 30 to reduce conflict with the crab pot fishery.

Management Considerations for Neuse River

If a complete closure or an option that closes areas in the northern and western portion of Pamlico Sound is chosen, a complete closure of Neuse River should be strongly considered. If status quo or other smaller scale options are chosen for Pamlico Sound, additional options could be considered for Neuse River.

Because large portions of the Neuse River are already permanently or seasonally closed to trawling, additional small-scale closures may not significantly reduce bycatch. In addition, the existing six-foot contour closure creates connectivity between nursery areas and the Pamlico Sound allowing for a degree of unobstructed movement of shrimp and fish. However, areas near the mouths of Dawson, Green (Oriental), and Lower Broad Creek are excluded from the shallow water closure, allowing shrimp trawlers to harvest shrimp as they leave these creeks. Filling these gaps with additional closures at the mouths of these creeks would create a continuous closure between nursery area habitat and Pamlico Sound. The area around the mouth of Dawson Creek is not a popular area for shrimp trawling but the area around the mouth of Greens Creek is very popular for commercial and recreational trawlers and the mouth of Lower Broad Creek is a popular area for commercial trawlers. In 1999 and 2000, a shoreline buffer closed to shrimp trawling running along the channel markers from Dawson Creek to the mouth of Neuse River was implemented by proclamation to address protection of small shrimp while allowing for shrimp trawling in the main stem of the river (NCDMF 2006). However, this buffer was difficult to enforce and often resulted in the same size shrimp being found on the open side of the line as on the closed side.

Parts of Clubfoot Creek, Adams Creek, South River, and Turnagain Bay are open to shrimp trawling to allow access to the shrimp resource but are located adjacent to PNA and SNA designations. Prohibiting shrimp trawling in these creeks would create a broader linkage between PNA’s and SNA’s and habitats used as the species grow and move. Restricting trawling in smaller tributaries could allow juvenile fish and crustaceans to disperse into larger water bodies where the probability of interacting with trawls is decreased, potentially reducing bycatch.

Example Options for Neuse River (Dependent on selected options for Pamlico Sound)

If all of Pamlico Sound or large areas in northern and western Pamlico Sound are closed, a complete closure of Neuse River should be the only option considered.

4. Prohibit shrimp trawling in Neuse River and its tributaries in combination with Pamlico Sound closures.
   + Reduces bycatch
   + Reduces conflict between trawlers and other sectors
   + Creates increased area for juvenile fish to disperse into larger water bodies
   + Creates a complete closure link between Neuse River and Pamlico Sound
   + Habitat protections
   - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
   - May increase trawl effort in open areas
   - Particularly limiting to smaller commercial and recreational shrimpers
   - Would limit brown shrimp fishery

If status quo or smaller scale options are chosen for Pamlico Sound, additional options could be considered for Neuse River.

5. *Status Quo* – No additional area or seasonal closures for Neuse River and its tributaries
   + Continues to allow access to the shrimp resource in Neuse River and open tributaries
   + No impact to shrimp trawling industry
   + Bycatch reductions may still be achieved through other strategies (i.e., gear modifications)
   - No additional bycatch reductions from area closures
   - Continued conflict between trawlers and other sectors

6. Close open areas in Clubfoot Creek, Adams Creek, South River, Turnagain Bay and the mouths of Dawson, Greens and Lower Broad Creek
   + Continues to allow access to the shrimp resource in most of Neuse River
   + Impact to the shrimp trawling industry is minimized
   + Additional closures in combination with other strategies (i.e., gear modifications) may reduce bycatch
   + Reduces some conflict between trawlers and other sectors
   + Allows juvenile fish more area to disperse before becoming susceptible to trawls
   + Creates continuous connectivity of closed area between Neuse River and Pamlico Sound
   - Limits access to shrimp resource is areas that might be very productive for shrimp harvest
   - May increase trawl effort in open areas
   - May not reduce bycatch
   - Particularly limiting to smaller commercial and recreational shrimpers
   - Would limit brown shrimp fishery

7. Prohibit shrimp trawling in Neuse River and its tributaries
   + Closure in combination with other strategies (i.e., gear modifications) may reduce bycatch
   + Reduces conflict between trawlers and other sectors
   + Creates increased area for juvenile fish to disperse into larger water bodies
   + Creates a complete closure link between Neuse River and Pamlico Sound
   + Habitat protections
   - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
   - May increase trawl effort in open areas
   - Particularly limiting to smaller commercial and recreational shrimpers
   - Would limit brown shrimp fishery

BAY RIVER

Bay River is a tributary of Pamlico Sound, located in Pamlico County, between the Pamlico and Neuse rivers. From 1994 to 2019, Bay River accounted for 0.2% of shrimp landings in the Pamlico area (Pamlico Sound, Bay River, Pamlico/Pungo River; Table 2.3.6), 1.3% of the trips, and 2.8% of participants (Table 2.3.7). Within the Pamlico Region, the Bay River has accounted for 0.2% of the value (Figure 2.3.5). The disparity between landings and trips suggests most of the shrimp trawl effort in the river is by smaller boats. Landings and trips have declined substantially since the late 1990s and early 2000s but have little trend since. Brown shrimp are the primary species caught in Bay River accounting for nearly all landings.

Shrimp trawling is only allowed in the main stem of the river because all tributary creeks and bays are classified as PNA, SNA, or no trawl areas (Appendix 3, Map 3.3). The area of the river, open to trawling, bound by the shoreline to the depth of six feet is closed to trawling from June 1 through November 30. Despite its smaller size, Bay River is a major area for small and larger commercial shrimp trawlers.

Management Considerations for Bay River

If a complete closure or an option that closes areas in the northern and western portion of Pamlico Sound is chosen, a complete closure of Bay River should be strongly considered. If status quo or other smaller scale options are chosen for Pamlico Sound additional options could be considered for Bay River.

Because large portions of Bay River are already permanently or seasonally closed to trawling, additional small-scale closures may not significantly reduce bycatch. In addition, the existing six-foot contour closure creates connectivity between Bay River nursery areas and the Pamlico Sound allowing for a degree of unobstructed movement of shrimp and fish between these areas. However, areas near the mouths of Vandemere Creek and along the eastern shore of Moore Bay are not included in this closure. Filling these gaps with additional closures would create a continuous closed area between nursery habitat and the Pamlico Sound.

Example Options for Bay River (Dependent on selected options for Pamlico Sound)

If all of Pamlico Sound or large areas in northern and western Pamlico Sound are closed, a complete closure of Bay River should be the only option considered.

8. Prohibit shrimp trawling in Bay River and its tributaries
   + Reduces bycatch
   + Reduces conflict between trawlers and other sectors
   + Creates increased area for juvenile fish to disperse into larger water bodies
   + Creates a complete closure link between Bay River and Pamlico Sound
   + Habitat protections
   - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
   - May increase trawl effort in open areas
   - Particularly limiting to smaller commercial and recreational shrimpers
   - Would limit brown shrimp fishery

If status quo or smaller scale options are chosen for Pamlico Sound, additional options could be considered for Bay River.

9. *Status Quo* - No additional area or seasonal closures in Bay River
   + Continues to allow access to the shrimp resource in Bay River
   + No impact to shrimp trawling industry
   + Bycatch reductions may still be achieved through other strategies (i.e., gear modifications)
   - No additional bycatch reductions from area closures
   - Continued conflict between trawlers and other sectors

10. Prohibit shrimp trawling at the mouth of Vandemere Creek and the shoreline area of Moore Bay
   + Continues to allow access to the shrimp resource in most of Bay River
   + Impact to the shrimp trawling industry is minimized
   + Additional closures in combination with other strategies (i.e., gear modifications) may reduce bycatch
   + Reduces some conflict between trawlers and other sectors
   + Allows juvenile fish more area to disperse before becoming susceptible to trawls
   + Creates continuous connectivity of closed area between Bay River and Pamlico Sound
   - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
   - May increase trawl effort in open areas
   - May not reduce bycatch
   - Particularly limiting to smaller commercial and recreational shrimpers
   - Would limit brown shrimp fishery

11. Prohibit shrimp trawling in Bay River
    + Closure in combination with other strategies (i.e., gear modifications) may reduce bycatch
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    + Creates a complete closure link between Bay River and Pamlico Sound
    + Habitat protections
    - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
    - May increase trawl effort in open areas
    - May not reduce bycatch
    - Particularly limiting to smaller commercial and recreational shrimpers
    - Would limit brown shrimp fishery

PAMLICO/PUNGO RIVER

From 1994 to 2019, the Pamlico/Pungo River accounted for 0.5% of shrimp landings in the Pamlico area (Pamlico Sound, Bay River, Pamlico/Pungo River; Table 2.3.6), 1.4% of the trips, and 5.0% of participants (Table 2.3.7). Within the Pamlico Region, the Pamlico/Pungo River has accounted for 0.5% of the value (Figure 2.3.5). Landings and trips have both declined substantially since the late 1990s and early 2000s. In 2014 no landings or trips were attributed to the Pamlico/Pungo River and in 2019, 194 pounds were attributed to the Pamlico/Pungo River. Brown shrimp are the primary species caught in the Pamlico/Pungo River accounting for nearly all shrimp landings.

Trawling is prohibited in the Pungo River and upstream of a line running from Pamlico Beach southwest to a point at Reed Hammock (Appendix 3, Map 3.3). These closures were implemented through the 2006 Shrimp FMP based on management recommendations from the 2005 Southern Flounder FMP to address the issue of sublegal southern flounder discards in the shrimp trawl fishery (NCDMF 2006). Trawling is allowed in lower Goose Creek north of a line running from the north shore of Snode Creek easterly to Store Point though tributaries of the creek are designated as PNA or SNA and are closed to trawling. The open area of Pamlico River bound by the shoreline to the depth of six feet is closed to trawling from June 1 through November 30. This includes the open portion of lower Goose Creek.

Management Considerations for Pamlico/Pungo River

If a complete closure or an option that closes areas in the northern and western portion of Pamlico Sound is chosen, a complete closure of Pamlico/Pungo River should be strongly considered. If status quo or other smaller scale options are chosen for Pamlico Sound additional options could be considered for Pamlico/Pungo River.

Because nearly all of Pamlico River is permanently or seasonally closed to trawling, additional small-scale closures may not significantly reduce bycatch. In addition, the existing six-foot contour closure creates connectivity between nursery areas and the Pamlico Sound allowing for a degree of unobstructed movement of shrimp and fish. The only gap in this closure occurs near the mouth of the Pungo River because water depth is greater than six feet. Filling this gap with a trawl closure would create a continuous closed area between nursery habitats and the Pamlico Sound.

The area of lower Goose Creek that is open to trawling is adjacent to PNA and SNA designations. Prohibiting trawling in lower Goose Creek would create a broader linkage between PNA and SNA habitats and habitats used as the species grow and move. Restricting trawling in smaller tributaries could allow juvenile fish to disperse into larger water bodies where the probability of interacting with trawls is decreased potentially reducing bycatch. However, lower Goose Creek is an important area to recreational shrimpers because of easy access and high productivity of shrimp.

Example Options for Pamlico/Pungo River (Dependent on selected options for Pamlico Sound)

If all of Pamlico Sound or large areas in northern and western Pamlico Sound are closed, a complete closure of Pamlico/Pungo River should be the only option considered.

12. Prohibit shrimp trawling in Pamlico/Pungo River and its tributaries
    + Reduces bycatch
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    + Creates a complete closure link between Pamlico/Pungo River and Pamlico Sound
    + Habitat protections
    - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
    - May increase trawl effort in open areas
    - Particularly limiting to smaller commercial and recreational shrimpers
    - Would limit brown shrimp fishery

If status quo or smaller scale options are chosen for Pamlico Sound, additional options could be considered for Pamlico/Pungo River.

13. *Status Quo* - No additional area or seasonal closures in Pamlico/Pungo River and its tributaries
    + Continues to allow access to the shrimp resource in Pamlico River
    + No impact to shrimp trawling industry
    + Bycatch reductions may still be achieved through other strategies (i.e., gear modifications)
    - No additional bycatch reductions from area closures
    - Continued conflict between trawlers and other sectors

14. Prohibit shrimp trawling in lower Goose Creek and at the mouth of Pungo River
    + Continues to allow access to the shrimp resource in most of Pamlico River
    + Impact to the shrimp trawling industry is minimized
    + Additional closures in combination with other strategies (i.e., gear modifications) may reduce bycatch
    + Reduces some conflict between trawlers and other sectors
    + Allows juvenile fish more area to disperse before becoming susceptible to trawls

+ Creates increased area for juvenile fish to disperse into larger water bodies
+ Creates continuous connectivity of closed area between Pamlico River and Pamlico Sound
- Limits access to shrimp resource in areas that might be very productive for shrimp harvest
- May increase trawl effort in open areas
- May not reduce bycatch
- Particularly limiting to recreational shrimpers
- Would limit brown shrimp fishery

15. Prohibit shrimp trawling in Pamlico River
    + Closure in combination with other strategies (i.e., gear modifications) may reduce bycatch
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    + Creates a complete closure link between Pamlico River and Pamlico Sound
    + Habitat protections
    - Limits access to shrimp resource in areas that might be very productive for shrimp harvest
    - May increase trawl effort in open areas
    - May not reduce bycatch
    - Particularly limiting to smaller commercial and recreational shrimpers
    - Would limit brown shrimp fishery

Northern Area

Discussion of commercial shrimp landings and trips for the Northern Region do not include areas north of Croatan and Roanoke sounds (i.e., Albemarle and Currituck sounds). Since 1987, it has been unlawful to use trawl nets in Albemarle Sound and its tributaries (15A NCAC 03J .0104(b)(3); Appendix 3, Map 3.4). This action was implemented to protect the flounder gill net fishery in this area (NCDMF 2006) and because of conflicts between trawlers and crab potters (NCDMF 2015). Because of high freshwater inputs, shrimp abundance is not high in Albemarle Sound, but minimal shrimp landings have occurred from non-trawl gear (i.e., crab pots, cast nets, pound nets, etc.) since 1994 (i.e., Albemarle Sound, Alligator River, Pasquotank River, Currituck Sound).

CROATAN SOUND

Croatan Sound is bound by Pamlico Sound to the south, extends along the west side of Roanoke Island, to Albemarle Sound to the north. From 1994 to 2019, Croatan Sound accounted for 67.9% of shrimp landings in the Northern Region (Croatan and Roanoke sounds), 51.1% of the trips, and 51.7% of participants (Table 2.3.9). Within the Northern Region, Croatan Sound has accounted for 69.0% of the value (Figure 2.3.18). Landings and trips have both increased substantially since around 2014, because of increased white shrimp landings. Historically, brown shrimp were the primary species landed from Croatan Sound, but landings of white shrimp began increasing in 2016.

There is no trawling permitted north of a line running northwesterly from the north end of Roanoke Island to Caroon Point (Appendix 3, Map 3.4). Except for feeder creeks and two oyster seed management areas along the southern part of Roanoke Island being closed to trawling there are no other trawling restrictions in Croatan Sound.

ROANOKE SOUND

Roanoke Sound extends north from Oregon Inlet along the east side of Roanoke Island to Albemarle Sound. From 1994 to 2019, Roanoke Sound accounted for 32.1% of shrimp landings in the Northern Region (Croatan and Roanoke sounds), 48.9% of the trips, and 48.3% of participants (Table 2.3.9). Within the Northern Region, Roanoke Sound has accounted for 30.3% of the value (Figure 2.3.18). Landings and trips have both increased substantially since around 2015 because of increased white shrimp landings. Historically, brown shrimp have accounted for most of the landings from Roanoke Sound. While Roanoke Sound accounts for nearly half of the trips in the Northern Region, landings are much lower than in Croatan Sound suggesting this area is trawled by smaller boats or is less productive for shrimp.

Shrimp trawling in allowed in most of Roanoke Sound but shallow water and other impediments limit the amount of area that can be trawled (Appendix 3, Map 3.4). Except for Outer Broad Creek, all feeder creeks and bays are designated as PNA, SNA, or no trawl areas. SSNAs are designated in Shallowbag Bay and the Kitty Hawk and Buzzards Bay area between the east side of Colington Island and the west side of Kill Devil Hills (see *Appendix 2.2: Management of Special Secondary Nursery Areas* for further information).

Management Considerations for Croatan Sound and Roanoke Sound

Because of proximity and connection, Croatan and Roanoke sounds should be combined when considering management options. If a complete closure or an option that closes areas in the northern and western portions of Pamlico Sound is chosen, a complete closure of Croatan and Roanoke sounds should be strongly considered. If status quo or other smaller scale options are chosen for Pamlico Sound additional options could be considered for Croatan Sound.

Because Roanoke Sound is a smaller waterbody with limited areas where shrimp trawling can occur, comprehensive potential area closures are not discussed. In addition, because of the SSNAs adjacent to Roanoke Sound and the presence of extensive critical habitat (i.e., SAV and shell bottom), options relating to additional area closures in Roanoke Sound are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas*.

Croatan and Roanoke sounds are small, shallow waterbodies with some areas of deeper water that contribute minimally to the shrimp fishery in North Carolina. This area acts as a major corridor for the movement of fish, particularly Atlantic croaker (Figure 2.3.6) and summer flounder (Figure 2.3.9), and invertebrates (i.e., blue crab; NCDMF 2020f) between Albemarle Sound and the ocean. Because of migration timing, habitat use, and other life history characteristics anadromous species like striped bass (*Morone saxatilis*), alewife (*Alosa pseudoharengus*), blueback herring (*A.*

aestivalis), and American shad (*A. sapidissima*) that use this area as a migration pathway between coastal rivers and the ocean are not a concern as bycatch in the estuarine shrimp trawl fishery. Consideration of Croatan and Roanoke Sound area closures should consider decisions regarding Pamlico Sound area closures. The objective of area closures in Croatan and Roanoke sounds should be creating connectivity between the closed area in the Albemarle Sound, Pamlico Sound, and the ocean.

Example Options for Croatan Sound and Roanoke Sound (Dependent on selected options for Pamlico Sound)

If all of Pamlico Sound or large areas in northern and western Pamlico Sound are closed, a complete closure of Croatan and Roanoke sounds should be the only option considered.

16. Prohibit shrimp trawling in Croatan and Roanoke sounds
    - \+ Reduces bycatch
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger waterbodies
    - \+ Creates a complete closure link between Croatan Sound and Pamlico Sound
    - \+ Habitat protections
    - \- Limits access to shrimp resource in areas that might be very productive for shrimp harvest
    - \- May increase trawl effort in open areas
    - \- May not reduce bycatch
    - \- Particularly limiting to smaller commercial and recreational shrimpers
    - \- Would limit brown shrimp fishery

If status quo or smaller scale options are chosen for Pamlico Sound, it would be difficult to consider additional small-scale options for Croatan Sound. Note that area closures may be considered for Roanoke Sound in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2 Management of Special Secondary Nursery Areas*.

17. *Status Quo* - No additional area or seasonal closures in Croatan and Roanoke sounds
    - \+ Continues to allow access to the shrimp resource in Croatan and Roanoke sounds
    - \+ No impact to shrimp trawling industry
    - \+ Bycatch reductions may still be achieved through other strategies (i.e., gear modifications)
    - \- No additional bycatch reductions from area closures
    - \- Continued conflict between trawlers and other sectors

18. Prohibit shrimp trawling in Croatan and Roanoke sounds
    - \+ Closure in combination with other strategies (i.e., gear modifications) may reduce bycatch
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \+ Creates a complete closure link between Croatan Sound and Pamlico Sound

+ Habitat protections
- Limits access to shrimp resource in areas that might be very productive for shrimp harvest
- May increase trawl effort in open areas
- May not reduce bycatch
- Particularly limiting to smaller commercial and recreational shrimpers
- Would limit brown shrimp fishery

<u>Central Area</u>

This section discusses areas where shrimp trawling occurs, characteristics of those areas and existing closed areas in the Central Area. Because of the smaller waterbodies in the Central Area and the limited areas where shrimp trawling can occur, comprehensive potential area closures are not discussed. Because of the numerous SSNAs in the Central Area and the presence of extensive critical habitat (i.e., SAV and shell bottom), options relating to additional area closures in the Central area are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas*.

CORE SOUND

Core Sound is a relatively small and shallow body of water that has maximum depths around ten feet with shrimp trawling occurring in the sound and its bays. From 1994 to 2019, Core Sound accounted for 56.0% of shrimp landings in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River; Table 2.3.10), 61.5% of the trips, and 46.6% of participants (Table 2.3.11). Within the Central Region, Core Sound has accounted for 64.0% of the value (Figure 2.3.19). Landings and trips have both generally declined since the early 2000s. Historically brown shrimp accounted for most of the shrimp landings from Core Sound followed by pink shrimp, but since 2010 white shrimp have made up a larger portion of the landings while pink shrimp landings have declined.

The area on the eastern side of Core Sound is designated as a no trawl area by Rule 15A NCAC 03R .0106 (1) and is in place to protect SAV but can be opened to peeler crab trawling by proclamation (Rule 15A NCAC 03J .0104 (4); Appendix 3, Map 3.5). The bays on the mainland side of Core Sound including Jarrett Bay, Brett Bay, Nelson Bay, Thorofare Bay-Barry Bay and Cedar Island Bay are designated as SSNAs which can be opened to trawling by proclamation from August 16th to May 14th. All other tributaries and bays to Core Sound are designated as PNAs. The only other shrimp trawling restriction in the area is the crab spawning sanctuary at Ophelia and Drum inlets which is closed to the use of bottom disturbing gear from March 1 to August 31. Refer to the *Appendix 2.2: Management of Special Secondary Nursery Areas* issue paper for detailed description of opening and closing dates of SSNAs in the Core Sound Area.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Management of Special Secondary Nursery Areas*.

19. Complete Closure of Core Sound
    + Reduces bycatch
    + Protects critical habitat
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    - Eliminates shrimp trawling in the most important area in the Central Area
    - May increase trawl effort in open areas
    - Particularly limiting to smaller commercial and recreational shrimpers

BOGUE SOUND

Bogue Sound is a relatively small and shallow body of water located in Carteret County between the State Port in Morehead City to the east and the town of Emerald Isle to the west and has maximum depths around five feet. From 1994 to 2019, Bogue Sound has accounted for 4.8% of shrimp landings in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River; Table 2.3.10), 5.4% of the trips, and 11.0% of participants (Table 2.3.11). Within the Central Region, Bogue Sound has accounted for 4.4% of the value (Figure 2.3.19). There has been little trend in landings or trips since 1994. White shrimp have generally accounted for most landings from Bogue Sound.

Tributaries including Pettiford, Goose, Sanders, Broad, Gales, and Archer creeks are designated as PNAs and the sound is closed to trawling north of the Intracoastal Water Way (IWW) on the mainland side (Appendix 3, Map 3.5-3.6). The closure of the mainland side of the IWW serves as a buffer zone to the PNAs and SAV habitat. There is also a rectangular section of Bogue Sound in the western portion that is closed to trawling to protect seagrass beds and bay scallop habitat (NCDMF 2007). Some nearshore areas on the south side of Bogue Sound, including Tar Landing Bay, Coral Bay and Hoop Pole Creek are also closed to trawling. Crab spawning sanctuaries, where trawling is prohibited from March 1 to October 31, have been designated at Beaufort and Bogue inlets. Shrimp are harvested from the IWW as they migrate toward the inlets (Beaufort and Bogue).

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

20. Complete Closure of Bogue Sound
    + Reduces bycatch
    + Protects critical habitat
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    - Eliminates shrimp trawling in a potentially productive area
    - May increase trawl effort in open areas
    - Particularly limiting to smaller commercial and recreational shrimpers

NORTH RIVER

North River is a relatively small and shallow body of water that has maximum depths around five feet. From 1994 to 2019, North River accounted for 14.0% of shrimp landings in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River; Table 2.3.10), 11.3% of the trips, and 18.0% of participants (Table 2.3.11). Within the Central Region, North River has accounted for 12.4% of the value (Figure 2.3.19). There has been little trend in landings, though annual fluctuations can be large while trips have generally declined since the early 2000s. White shrimp have generally accounted for most landings from North River with some large peaks in brown shrimp landings.

Most of the upper portion of North River is designated as PNA or SSNA. Ward Creek and its tributaries are also designated as either PNA or SSNA (Appendix 3, Map 3.5-3.6). Turner Creek, a small tributary near the mouth of North River, is designated as PNA and other tributaries of the river are closed to trawling. Refer to the *Management of Special Secondary Nursery Areas* issue paper for detailed description of opening and closing dates of SSNAs in the Core Sound Area. The entire North River was closed to shrimp trawling once in 2003 (Proclamation SH-7-2003).

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

21. Complete Closure of North River
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

NEWPORT RIVER

Newport River is generally deeper than Bogue Sound and North River and has more area that can be trawled. From 1994 to 2019, Newport River has accounted for 20.5% of shrimp landings in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River; Table 2.3.10), 17.2% of the trips, and 18.2% of participants (Table 2.3.11). Within the Central Region, Newport River has accounted for 16.0% of the value (Figure 2.3.19). Landings and trips have generally been declining since the early 2000’s, though annual fluctuations are large. White shrimp have generally accounted for most landings from Newport River with lesser, but consistent, landings of brown shrimp.

The upper portion of the Newport River is permanently closed to trawling through the 2006 FMP and encompasses PNA and SSNA (NCDMF 2006; Appendix 3, Map 3.5-3.6). Through management recommendations in Amendment 1, the Newport River SSNA was re-designated as an SNA (NCDMF 2015). Except for Core Creek, most tributaries and bays of the Newport River including Calico Creek, Crab Point Bay, Harlow Creek, Oyster Creek, Eastman Creek, Bell Creek, Ware Creek, and Russel Creek are designated as PNAs. There are no other trawling restrictions in the Newport River.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

22. Complete Closure of Newport River
    + Reduces bycatch
    + Protects critical habitat
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    - Eliminates shrimp trawling in a potentially productive area
    - May increase trawl effort in open areas
    - Particularly limiting to smaller commercial and recreational shrimpers

WHITE OAK RIVER

White Oak River is located on the Onslow/Carteret County line and has the town of Swansboro at its mouth. Due to the presence of oyster rocks and shoals, there are only a few places that are trawled in the river. From 1994 to 2019, White Oak River accounted for 4.7% of shrimp landings in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River; Table 2.3.10), 4.5% of the trips, and 6.1% of participants (Table 2.3.11). Within the Central Region, White Oak River has accounted for 3.1% of the value (Figure 2.3.19). Landings and trips have generally declined since the early 2000's, though annual fluctuations are large. White shrimp account for most landings from White Oak River.

The middle portion of the White Oak River above Cahoon's Slough across to Hancock Point was closed to trawling through the 2006 FMP (NCDMF 2006; Appendix 3, Map 3.5-3.6). The upper portion of the river and tributaries including Pettiford Creek, Holland Mill Creek, Hawkins Creek, and parts of Queens Creek are designated as PNAs. There are no other trawling restrictions in the White Oak River.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.1: Management of Special Secondary Nursery Areas*.

23. Complete Closure of White Oak River
    + Reduces bycatch
    + Protects critical habitat
    + Reduces conflict between trawlers and other sectors
    + Creates increased area for juvenile fish to disperse into larger water bodies
    - Eliminates shrimp trawling in a potentially productive area
    - May increase trawl effort in open areas
    - Particularly limiting to smaller commercial and recreational shrimpers

Southern Area

This section discusses areas where shrimp trawling occurs, characteristics of those areas and existing closed areas in the Southern Area. Because of the smaller waterbodies in the Southern Area and the limited areas where shrimp trawling can occur, comprehensive potential area closures are not discussed. Because of the numerous SSNAs in the Southern Area and the extensive presence of critical habitat (i.e., SAV and shell bottom), options relating to additional area closures in the Southern Area are discussed in *Appendix 2: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas*.

INTRACOASTAL WATERWAY AND SOUNDS FROM QUEENS CREEK TO HOLOVER CREEK

Queens and Bear creeks are usually opened to shrimp trawling in conjunction with White Oak River (NCDMF 2006). Queens Creek is located southeast of the White Oak River in Onslow County. The waters upstream of the NC 1509 Bridge and the tributary creeks below the bridge (Halls, Parrot Swamp, and Dicks creeks) are designated as a PNAs and are closed to trawling. Limited trawling occurs below the bridge by skimmer trawlers and RCGL holders. Bear Creek is a shallow water creek located south of Queens Creek. In Bear Creek, the waters upstream of the closure line at Willis Landing are designated as PNA and are closed to trawling and very limited trawling occurs below Willis Landing due to the presence of shoals. Browns, Freeman, Gillets, and Holover creeks as well as Salliers Bay are designated as PNAs and are closed to trawling. The bays and tributaries that surround the IWW from Queens Creek to Holover Creek are designated as PNAs and are closed to trawling; however, trawling is allowed in the main channel of the IWW. Trawling is allowed in channels that connect the IWW to the ocean (West and Suanders/Sander creeks). From March 1 to October 31 trawling is prohibited in the designated crab spawning sanctuary at Bear and Browns inlets.

In 2002, the NCTTP waterbody code for the “Inland Waterway” was split into two waterbody codes [Inland Waterway (Onslow), Inland Waterway (Brunswick)]; however, some dealers using older trip tickets continued to use the code up until 2007. Thus, landings from 2003-2019 do not reflect total landings, trips, and participants from this waterbody and are not shown.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

24. Complete Closure of IWW and Sounds from Queens Creek to Holover Creek
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

NEW RIVER

The New River is approximately 50 miles long and is in Onslow County (Appendix 3, Map 3.7-3.8). The lower portion of the river adjoins portions of Bogue and Topsail sounds via the IWW. The Chadwick Bay SSNA also borders the lower portion of the New River (see *Appendix 2.2: Management of Special Secondary Nursery Areas*). In 1995, the waters upstream of the Highway 172 bridge were designated as SSNA. The use of otter trawls in the SSNA was phased out in 2010 as part of the 2006 Shrimp FMP. Trawling is prohibited in all tributary creeks downstream of the closure line at Grey and Wards Point and in the military restricted zone that extends from the western shoreline of the river below Grey Point to the northeastern shoreline of Stones Bay. NCDMF actively manages eight Shellfish Management Areas (SMAs) that are closed to trawling in the area. Below the Highway 172 Bridge, trawling is prohibited in all bays and tributary creeks and additional areas were closed to match the mechanical clam harvest line to protect SAV. From March 1 to October 31 trawling is prohibited in the designated crab spawning sanctuary at New River Inlet.

Landings from New River (above and below Highway 172 Bridge) accounted for 49.8% of shrimp landings in the Southern Region (Cape Fear River, Inland Waterway, Inland Waterway (Brunswick), Inland Waterway (Onslow), Lockwood’s Folly, Masonboro Sound, New River, Shallotte River, Stump Sound, Topsail Sound; Table 2.3.12), 41.8% of the trips and 37.5% of participants from 1994 to 2019 (Table 2.3.13 and 2.3.14). Within the Southern Region, New River has accounted for 53.8% of the value (Figure 2.3.20). While landings and trips have declined since the 1990s, landings from the New River made up 72.4% of the total landings from the Southern Region in 2019. Historically, brown shrimp made up roughly a quarter of the landings; however, over the last decade white shrimp have comprised approximately 70% of the landings.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

25. Complete Closure of New River
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

INTRACOASTAL WATERWAY AND SOUNDS FROM NEW RIVER TO RICH INLET

The estuarine waters of the IWW as well as the adjacent sounds and bays between the New River Inlet and Rich Inlet are managed as a single waterbody. Stump Sound lies between Marker #17 to the site of the “old” Highway 50 Bridge at Surf City and includes the waters of Alligator, Everett, Spicer, and Waters bays. Topsail Sound includes all waters south of the Highway 50 Bridge to Old Topsail Inlet. Landings from Stump and Topsail sounds accounted for 12.1% of shrimp landings in the Southern Region (Cape Fear River, Inland Waterway, Inland Waterway (Brunswick), Inland Waterway (Onslow), Lockwood's Folly, Masonboro Sound, New River, Shallotte River, Stump Sound, Topsail Sound; Table 2.3.12), 16.4% of the trips, and 20.6% of participants from 1994 to 2019 (Table 2.3.13 and 2.3.14). Within the Southern Region, Stump and Topsail sounds have accounted for 11.0% of the value (Figure 2.3.20). Since the 1990s, landings and trips have declined in both areas. Historically, brown shrimp made up a large percentage of the landings; however, white shrimp have accounted for over 60% of the landings since 2016.

Trawling is allowed in the IWW main channel from Marker #72A in the New River to Marker #17 in Stump Sound (Appendix 3, Map 3.8-3.10). The tributaries and bays adjacent to the IWW are designated as PNAs and are closed to trawling. The area south of Marker #17 to the site of the old Highway 50 Bridge at Surf City is designated as SSNA and may be opened to trawling from August 16 through May 14. Trawling in the SSNA is primarily limited to the main channel only; however, trawling is allowed within 100 ft on either side of the channel from Marker #49 to the Surf City Bridge. South of the SSNA, trawling is allowed within 100 ft on either side of the channel to Marker #93. Trawling is restricted to the main channel only throughout the rest of the IWW to Rich Inlet. Trawling is allowed in channels that connect the IWW to the ocean (Howards and Green channel). The division maintains three SMAs throughout Topsail and Stump sounds as well as an oyster sanctuary in Stump Sound, all of which are located in waters closed to shrimp trawling. Trawling is further prohibited from March 1 to October 31 in crab spawning sanctuaries, located at New Topsail and Rich inlets.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

26. Complete Closure of IWW and Sounds from New River to Rich Inlet
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

INTRACOASTAL WATERWAY AND SOUNDS FROM RICH INLET TO CAROLINA BEACH INLET

The estuarine waters of the IWW and adjacent sounds between Rich Inlet and Carolina Beach stretch over 21 miles and include four inlets separating four barrier islands, three of which (Figure Eight, Wrightsville, Carolina Beach) are heavily developed. The IWW stretches across Masonboro and Myrtle Grove sounds and are regularly dredged for navigation purposes. Landings from this area accounted for 0.9% of shrimp landings in the Southern Region (Cape Fear River, Inland Waterway, Inland Waterway (Brunswick), Inland Waterway (Onslow), Lockwood's Folly, Masonboro Sound, New River, Shallotte River, Stump Sound, Topsail Sound; Table 2.3.12), 1.5% of the trips, and 2.9% of participants from 1994 to 2019 (Table 2.3.13 and 2.3.14). Within the

Southern Region, the IWW and sounds from Rich Inlet to Carolina Beach Inlet accounted for 0.7% of the value (Figure 2.3.20). Landings and effort have sharply declined since 1994; no shrimp landings or trips were reported in 2018 and 2019. Shrimp from this area are smaller in size (40-50 shrimp per pound on average) relative to other waterbodies and are often sold as live bait. Over the last decade, white shrimp have accounted for almost 80% of the landings.

Many of the bays, creeks, and tributaries that surround the IWW from Rich Inlet to Carolina Beach are designated as PNAs and SNAs and are closed to trawling (Appendix 3, Map 3.8-3.10). Trawling is restricted to the main channel throughout the waterway; however, trawling is allowed in the Carolina Beach Yacht Basin as well as channels that connect to the Atlantic Ocean (Nixon Channel, Mason Channel, Stokley Cut/Old Moores Inlet Channel, Lee's Cut/Spring Landing Channel, Banks Channel, and Mott Channel). The area from Marker #105 to the Wrightsville Beach drawbridge was closed to trawling following the adoption of the 2006 Shrimp FMP. Actions were also taken as part of the 2006 FMP to manage the IWW from Marker #139 to Marker #146 (William's Landing) as a SSNA, opening by proclamation from August 16 through May 14. Due to the abundance of small shrimp and limited interest, this area has not opened since 2014 (SH-12-2014). Within the waters from Rich Inlet to Carolina Beach, the division maintains six SMAs as well as an oyster sanctuary at the mouth Hewlett's Creek, all of which are closed to trawling. Trawling is further prohibited from March 1 to October 31 in crab spawning sanctuaries, located at Rich, Mason, Masonboro, and Carolina Beach inlets.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

27. Complete Closure of IWW and Sounds from Rich Inlet to Carolina Beach Inlet
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

CAPE FEAR RIVER COMPLEX

The Cape Fear River complex includes the waters of the Wilmington Harbor navigation channel to the inlet and the bays behind Carolina and Kure Beach and Bald Head Island. The shrimp closure line in the Cape Fear River runs easterly across the river just upstream from the mouth of Lilliput Creek. Just downstream of this line, the upper portion of the shrimp trawl management area is connected to the IWW at Snow's Cut. The lower portion of the river adjoins the IWW at Marker #1 near Southport and borders the mouths of Dutchman Creek and the Elizabeth River. The Cape Fear River Complex accounted for 19.9% of shrimp landings in the Southern Region (Cape Fear River, Inland Waterway, Inland Waterway (Brunswick), Inland Waterway (Onslow), Lockwood's Folly, Masonboro Sound, New River, Shallotte River, Stump Sound, Topsail Sound; Table 2.3.12), 16.0% of the trips and 9.4% of participants from 1994 to 2019 (Table 2.3.13 and 2.3.14). Within the Southern Region, the Cape Fear River has accounted for 19.7% of the value (Figure 2.3.20). Landings have continuously declined since the 1990s. Over the last decade, white shrimp have accounted for approximately 80% of the landings on average. In general, shrimp caught in the Cape Fear River are smaller in size (40-50 shrimp per pound on average) relative to other parts of the state and are often sold as live bait or to local markets and breading operations.

Nearly all of the upper Cape Fear River is designated as PNA or Inland Waters and is therefore closed to shrimp trawling (Appendix 3, Map 3.11). Below Snow's Cut, trawling is allowed in the main river channel and behind many of the spoil islands. The areas known as the "Dow Chemical Bay" and "Radar Bay" are closed to trawling. Most trawl effort occurs outside the main channel from the Fort Fisher Ferry to Battery Island. Trawling, and all other boating activity, is prohibited in the military restricted area at the Sunny Point Military Ocean Terminal. The SSNA behind Kure Beach has not opened to trawling since being designated as SSNA in 1986, and shrimp trawling will no longer be allowed pending rule changes effective May 1, 2021 associated with Amendment 1 that re-designate this area as a permanent SNA (refer to the *Management of Special Secondary Nursery Areas issue paper* for a detailed description of this change). The bays south of the Fort Fisher Ferry Terminal (First Bay or "the Basin", Second Bay, Buzzard's Bay) and behind Bald Head Island (Cape and Bay creeks) were designated as Trawl Net Prohibited areas with the implementation of the 2006 Shrimp FMP. Trawling is further prohibited in the crab spawning sanctuary at the Cape Fear River Inlet from March 1 to October 31.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

28. Complete Closure of Cape Fear River complex
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

BRUNSWICK COUNTY

The Brunswick County coastline stretches approximately 33 miles across four barrier islands (Oak Island, Holden Beach, Ocean Isle, Sunset Beach) and is bound by the Little River Inlet on the west end and the Cape Fear River Inlet on the east end. Brunswick County (IWW, Shallotte River, Lockwood's Folly River) has accounted for 3.0% of shrimp landings in the Southern Region (Cape Fear River, Inland Waterway, Inland Waterway (Brunswick), Inland Waterway (Onslow), Lockwood's Folly, Masonboro Sound, New River, Shallotte River, Stump Sound, Topsail Sound; Table 2.3.12), 6.1% of the trips, and 7.7% of participants from 1994 to 2019 (Table 2.3.13 and 2.3.14). Within the Southern Region, Brunswick County has accounted for 2.7% of the value (Figure 2.3.20). Landings and trips have significantly declined since 2010. Historically, landings consisted of a mix of brown and white shrimp with numerous closures occurring throughout the

1990s and early 2000s to protect recruiting white shrimp. In recent years, limited effort and poor catches of brown shrimp have limited the need for closures to protect white shrimp. Over the last decade, white shrimp have made up over 60% of the landings in Brunswick County.

Trawling is Brunswick County is primarily limited to the main channel of the IWW. Most of the shoreline bordering the IWW is designated as nursery area and is closed to trawling (Appendix 3, Map 3.11-3.12). With the adoption of Amendment 1, shrimp trawling was prohibited in the IWW from the Sunset Beach Bridge to the South Carolina line, including the Shallotte River, Eastern Channel, and lower Calabash River to protect small shrimp and reduce bycatch. In February 2020, the MFC also recommend that the Lockwood Folly River and Saucepan Creek SSNAs be re-designated as permanent SNAs; thus, prohibiting all trawling. Rule changes are scheduled to be effective May 1, 2021 (refer to the *Management of Special Secondary Nursery Areas issue paper* for a detailed description of this change). Trawling is also prohibited in the Southport Boat Harbor and the Progress Energy Intake Canal. Trawling is allowed in the channels that connect the IWW to Atlantic Ocean, such as the Elizabeth River, Dutchman Creek, Montgomery Slough, Jinks Creek, and Bonaparte Creek. Trawling is prohibited from March 1 to October 31 in crab spawning sanctuaries located at Shallotte River Inlet, Lockwoods Folly Inlet, and Tubbs Inlet.

Example Option, additional options are discussed in *Appendix 2.1: Management of Shrimp Trawling for Protection of Critical Sea Grass and Shell Bottom Habitats* and *Appendix 2.2: Management of Special Secondary Nursery Areas*.

29. Complete Closure of Brunswick County
    - \+ Reduces bycatch
    - \+ Protects critical habitat
    - \+ Reduces conflict between trawlers and other sectors
    - \+ Creates increased area for juvenile fish to disperse into larger water bodies
    - \- Eliminates shrimp trawling in a potentially productive area
    - \- May increase trawl effort in open areas
    - \- Particularly limiting to smaller commercial and recreational shrimpers

VI. PROPOSED RULE(S)

This action will result in no immediate rulemaking, rather existing proclamation authority pertaining to use of trawls may be used.

VII. SHRIMP FMP WORKSHOPS

Shrimp FMP Workshops were held in March 2021 between the division plan development team and the Shrimp FMP Advisory Committee (AC). The goal of these workshops is for the AC to assist the division in drafting the plan. The division presented discussion points to guide conversation and inform specific areas where stakeholder input was needed in addition to other AC feedback. The guidance received during workshops on area closures to reduce bycatch was incorporated into the draft plan. Many AC members expressed hesitancy over implementing large scale area closures because they would be extremely detrimental to the shrimp trawl industry, would hurt the early season brown shrimp fishery, and would hurt small boats and skimmer trawlers more than larger boats. However, there was generally an acknowledgement that area closures, particularly the examples presented, would reduce bycatch. Some AC member expressed support for the approach presented but largely deferred to commercial AC members in identifying specific areas that might be considered for closure. There was a suggestion to take a more incremental approach, like closing areas near the river mouths and Croatan Sound and observing potential. There was generally support for allowing alternative gears that may not have significant bycatch concerns, like skimmer trawls, in closed areas. During the wrap up workshop there was a suggestion to delay the opening of Pamlico Sound to shrimp trawls based on count size of shrimp. Throughout the duration of the workshops there was discussion about the role Pamlico Sound potentially serves as a nursery for finfish. Some areas adjacent to Pamlico Sound are designated as primary or secondary nursery areas and this Amendment has an objective to "develop a strategy through the CHPP to review current nursery areas and to identify and evaluate potential areas suitable for designation". Work to meet this objective will be ongoing. Given this objective, it would be inappropriate to designate nursery areas through the shrimp FMP prior to a thorough scientific review, but shrimp trawl area closures can be considered based on information presented.

IX. RECOMMENDATION

The division will make recommendations after receiving input from the MFC Advisory Committees.

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Tables

Table 2.3.1. Commercial landings (pounds) and number of commercial trips and participants landing shrimp in North Carolina, 1994-2019.

Year	Landings	Trips	Participants
1994	7,284,793	21,768	1,580
1995	8,669,257	23,891	1,891
1996	5,261,147	17,085	1,513
1997	6,988,243	20,442	1,526
1998	4,635,189	14,969	1,196
1999	8,991,521	19,821	1,504
2000	10,334,915	18,442	1,725
2001	5,254,132	14,072	1,213
2002	9,969,018	18,342	1,372
2003	6,167,371	14,057	1,110
2004	4,880,816	11,882	988
2005	2,357,516	6,582	703
2006	5,736,649	8,025	715
2007	9,537,230	9,291	804
2008	9,414,418	8,084	849
2009	5,407,708	7,770	735
2010	5,955,335	7,864	755
2011	5,140,360	5,361	573
2012	6,141,480	8,924	755
2013	4,858,885	8,689	728
2014	4,690,933	6,478	642
2015	9,116,730	8,182	751
2016	13,195,269	9,727	896
2017	13,905,392	9,571	892
2018	9,729,526	6,097	739
2019	9,547,982	5,909	652
Total	193,171,815	311,325	26,807
Average	7,429,685	11,974	1,031

Table 2.3.2. Cumulative total count of the top 20 species captured in the Estuarine Trawl Survey (Program 120) from May and June, 2015-2019. Species in bold are those commonly associated with the North Carolina commercial shrimp trawl fishery.

Species	Count	Percent
Spot	**1,719,494**	**43.0**
Pinfish	685,624	17.2
Brown Shrimp	**419,500**	**10.5**
Atlantic Croaker	**345,241**	**8.6**
Bay Anchovy	335,827	8.4
Atlantic Menhaden	117,408	2.9
Silver Perch	86,129	2.2
Blue Crab	73,849	1.8
Pigfish	32,148	0.8
Southern Flounder	**30,170**	**0.8**
Rainwater Killifish	27,635	0.7
White Shrimp	**10,607**	**0.3**
Hogchoker	9,312	0.2
Inland Silverside	9,281	0.2
Atlantic Rangia	7,795	0.2
Naked Goby	5,910	0.1
Bluegill	5,776	0.1
Weakfish	**4,836**	**0.1**
Marsh Killifish	4,631	0.1
Fundulus Killifishes	3,897	0.1
Remaining 289 Species	.	1.6

Table 2.3.3. Cumulative total count and biomass (kg) of the top 20 species captured in the Pamlico Sound Survey (Program 195) from June and September, 2015-2019. Species in bold are those commonly associated with the North Carolina commercial shrimp trawl fishery.

June	Number		Biomass		September	Number		Biomass	
Species	Number	Percent	Weight (kg)	Percent	Species	Number	Percent	Weight (kg)	Percent
Atlantic Croaker	**485,083**	**39.7**	**9,941.0**	**28.8**	**Atlantic Croaker**	**428,071**	**37.7**	**12,774.2**	**35.6**
Spot	**455,062**	**37.2**	**10,396.7**	**30.1**	**Spot**	**376,797**	**33.1**	**9,843.6**	**27.5**
Blue Crab	97,915	8.0	4,852.5	14.1	**Weakfish**	**45,421**	**4.0**	**1,974.3**	**5.5**
Weakfish	**37,424**	**3.1**	**3,013.7**	**8.7**	Pinfish	40,419	3.6	1,583.9	4.4
Brown Shrimp	**20,904**	**1.7**	**246.8**	**0.7**	Atlantic Menhaden	28,586	2.5	524.9	1.5
Bay Anchovy	19,621	1.6	34.9	0.1	Bay Anchovy	21,439	1.9	33.0	0.1
Hogchoker	17,848	1.5	685.0	2.0	**White Shrimp**	**21,355**	**1.9**	**509.2**	**1.4**
Pinfish	16,365	1.3	648.2	1.9	Blue Crab	20,054	1.8	1,761.5	4.9
Atlantic Menhaden	13,023	1.1	365.4	1.1	Silver Perch	18,509	1.6	682.8	1.9
Silver Perch	11,616	1.0	615.8	1.8	Harvestfish	14,921	1.3	371.6	1.0
Pink Shrimp	**10,158**	**0.8**	**152.5**	**0.4**	Pigfish	12,999	1.1	539.8	1.5
Summer Flounder	**7,998**	**0.7**	**223.9**	**0.6**	**Pink Shrimp**	**11,599**	**1.0**	**109.4**	**0.3**
Southern Flounder	**6,698**	**0.5**	**420.5**	**1.2**	**Brown Shrimp**	**10,870**	**1.0**	**206.2**	**0.6**
Butterfish	2,993	0.2	106.5	0.3	Striped Anchovy	10,269	0.9	80.5	0.2
Mantis Shrimp	2,764	0.2	48.3	0.1	Atlantic Thread Herring	8,008	0.7	150.7	0.4
Lesser Blue Crab	2,015	0.2	14.6	0.0	Hogchoker	7,934	0.7	290.0	0.8
Southern Kingfish	1,653	0.1	182.0	0.5	Lesser Blue Crab	6,564	0.6	109.6	0.3
Atlantic Thread Herring	1,451	0.1	47.6	0.1	**Summer Flounder**	**6,487**	**0.6**	**381.4**	**1.1**
Harvestfish	1,292	0.1	141.6	0.4	Atlantic Spadefish	5,771	0.5	130.7	0.4
Pigfish	1,290	0.1	84.0	0.2	Gizzard Shad	4,920	0.4	110.4	0.3
Remaining 137 Species	.	0.8	.	6.6	Remaining 144 Species	.	3.2	.	10.3

Table 2.3.4. General life history characteristics of species commonly associated with the commercial shrimp trawl fishery in North Carolina.

Species	Spawning Period	Spawning Location	Larval Stage	Juvenile Stage	References
Brown Shrimp	February-March	Ocean	Enter estuaries February-April	Move to deeper portions of estuary as they grow	see NCDMF (2015) for review
Pink Shrimp	April-July	Ocean	Enter estuaries May-November	Move to deeper portions of estuary as they grow	see NCDMF (2015) for review
White Shrimp	March-November	Ocean	Enter estuaries May-July; 2-3 weeks after hatching	Move to deeper portions of estuary as they grow	see NCDMF (2015) for review
Atlantic croaker	October-March	Ocean; continental shelf	larvae enter estuaries late fall to late winter	Remain in upper estuarine habitats until mid-summer before moving into deeper open water habitats	see Odell et al. (2017) for review
Southern flounder	November-April	Ocean	Enter estuaries 30-45 days after hatching, settling throughout sounds and rivers in the winter and early spring	Overwinter in low salinity waters or rivers and bays for first two years of life before migrating offshore	see Flowers et al. (2019) for review
Summer flounder	Fall and early winter	Ocean	Enter estuary October-May	Spend first year in bays and other inshore areas	see Packer et al. (1999) for review
Spot	Fall-Winter	Ocean; continental shelf	Enter estuaries winter-early spring	As they grown move from shallow habitat to deeper water habitats	see Odell et al. (2017) for review
Weakfish	March-September	Nearshore ocean; lower reaches of estuaries	Larvae distribute throughout estuaries	Inhabit nearshore and deeper waters of bays, estuaries, and sounds	see Odell et al. (2017) for review

Table 2.3.5. Existing areas closed to the use of trawls in coastal and estuarine waters of North Carolina.

Type of Closure	Location	Restriction	Purpose	Reference
Primary Nursery Area	Statewide/Internal Coastal Waters	Unlawful to use trawl nets or other bottom disturbing gear	Protect habitat for juvenile fish and shrimp	15A NCAC 03N .0104 15A NCAC 03R .0103
Secondary Nursery Area	Statewide/Internal Coastal Waters	Unlawful to use trawl nets	Protect habitat for juvenile fish and shrimp	15A NCAC 03N .0105(a) 15A NCAC 03R .0104
Special Secondary Nursery Area	Statewide/Internal Coastal Waters	Can be opened to the use of trawl nets by proclamation from August 16 to May 14	Protect habitat for juvenile fish and shrimp while allowing taking of shrimp after they have grown or when juvenile fish have left area	15A NCAC 03N .0105 15A NCAC 03R .0105
Trawl Net Prohibited Areas	Statewide/Coastal and Internal Coastal Waters	Unlawful to use trawl nets; parts of Pamlico, Core and Back sounds can be opened to peeler crab trawling by proclamation	Protect sensitive habitat or reduce bycatch	15A NCAC 03J .0104(b)(3)(4) 15A NCAC 03R .0106
Military Danger Zones	Statewide/Coastal and Internal Coastal Waters	No public access	Public safety	15A NCAC 03R .0102
Crab Spawning Sanctuaries	All coastal inlets	From Barden Inlet north unlawful to use trawls in spawning sanctuaries from March 1 to August 31; From Beaufort inlet south unlawful to use trawls in spawning sanctuaries from March 1 to October 31	Provide protection for spawning blue crabs	15A NCAC 03L .0205 15A NCAC 03R .0110 Proclamation M-7-2020

Type of Closure	Location	Restriction	Purpose	Reference
Designated Pot Areas	Pamlico, Bay, Neuse rivers and their tributaries	Unlawful to use trawl nets in designated pot areas from June 1 to November 30	Reduce gear conflicts between trawls and crab pots	NCAC 03J .0104(b)(6) 15A NCAC 03J .0301(a)(2) 15A NCAC 03R .0107 Proclamation (i.e., SH-1-2020)
Seed Oyster Management Areas	Statewide/Internal Coastal Waters	Unlawful to use trawl nets in seed oyster management areas	Protect oyster habitat	15A NCAC 03K .0208 15A NCAC 03R .0116
Oyster Sanctuaries	Croatan Sound, Pamlico Sound, Neuse River	Unlawful to use trawl nets in oyster sanctuaries	Protect oyster habitat	15A NCAC 03k .0209 15A NCAC 03R .0117
Shrimp Trawl Prohibited Areas	Pungo, Pamlico, Neuse, Shallotte, Calabash rivers; Eastern Channel; Sunset Beach	Unlawful to use shrimp trawls	Protect habitat, reduce bycatch, reduce gear conflicts	15A NCAC 03L .0103(e) 15A NCAC 03R .0114
Other Trawl Closures				
Miscellaneous	Atlantic Ocean	Unlawful to use trawls in specified areas, during specified times	Protect habitat, reduce bycatch, reduce gear conflicts	15A NCAC 03J .0202 (1)(2) 15A NCAC 03J .0202 (8)
Miscellaneous	Albemarle Sound and Tributaries	Unlawful to use trawls	Protect habitat, reduce bycatch, reduce gear conflicts	15A NCAC 03J .0104 (b)(3)
Miscellaneous	Southport Boat Harbor	Unlawful to use any commercial fishing gear	Reduce user group conflict, public safety	15A NCAC 03J .0206
Miscellaneous	Duke Energy Progress Brunswick Nuclear Plant Intake Canal Closure	Unlawful to use any commercial fishing gear	Public safety	15A NCAC 03J .0207

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Type of Closure	Location	Restriction	Purpose	Reference
Miscellaneous	Dare County	Unlawful to use commercial fishing gear within 750 feet of licensed fishing piers when open to the public	Reduce user group conflict	15A NCAC 03J .0402(a)(1)(ii)
Miscellaneous	Onslow and Pender counties	Unlawful to use commercial fishing gear during specified times and distances from fishing piers	Reduce user group conflict	15A NCAC 03J .0402(a)(2)(A)(B)(i)(ii)
Miscellaneous	New Hanover County	Unlawful to use commercial fishing gear during specified times and distances from fishing piers	Reduce user group conflict	15A NCAC 03J 0402(a)(3)(A)(B)(i)(iii)

Table 2.3.6. Total commercial shrimp landings from each water body within the Pamlico Region (Pamlico Sound, Neuse River, Bay River, Pamlico/Pungo River), 1994-2019.

Year	Pamlico Sound	Neuse River	Bay River	Pamlico/Pungo River
1994	3,861,536	115,689	20,051	46,107
1995	4,096,835	114,705	10,021	34,756
1996	1,933,536	111,098	6,051	23,948
1997	3,722,785	164,538	16,409	41,096
1998	1,115,961	83,765	1,358	14,664
1999	3,876,339	216,922	27,913	50,703
2000	6,708,334	210,970	35,348	51,636
2001	2,890,943	19,942	5,935	27,090
2002	6,147,806	213,697	14,070	110,329
2003	2,023,826	102,366	2,010	11,944
2004	2,104,690	87,384	526	6,546
2005	558,104	110,286	1,915	4,367
2006	2,477,858	125,952	1,600	3,876
2007	6,761,768	139,720	858	30,015
2008	5,944,307	391,739	7,144	21,779
2009	3,686,102	116,298	4,192	18,710
2010	3,837,536	116,953	2,405	12,813
2011	3,636,369	115,586	6,069	399
2012	3,955,615	111,098	3,969	5,285
2013	3,041,974	107,772	3,230	4,352
2014	3,351,981	102,625	1,334	0
2015	6,529,484	188,902	21,613	17,844
2016	6,973,945	161,748	5,138	1,815
2017	8,542,675	168,309	3,361	2,640
2018	7,265,369	115,069	4,552	3,214
2019	2,897,791	85,715	383	194
Total	107,934,165	3,598,051	207,418	546,123
Average	4,151,314	138,387	7,978	21,005

Table 2.3.7. Total commercial trips and participants landing shrimp from each water body within the Pamlico Region (Pamlico Sound, Neuse River, Bay River, Pamlico/Pungo River), 1994-2019.

	Trips				Participants			
Year	Pamlico Sound	Neuse River	Bay River	Pamlico/Pungo River	Pamlico Sound	Neuse River	Bay River	Pamlico/Pungo River
1994	3,512	555	98	85	288	63	13	25
1995	4,154	620	71	59	303	77	14	39
1996	1,956	510	39	20	212	70	10	11
1997	3,132	862	106	65	267	78	14	21
1998	1,269	383	54	9	151	49	4	7
1999	3,124	559	78	57	286	57	8	23
2000	4,011	541	91	128	383	106	47	37
2001	2,800	155	55	89	283	32	14	37
2002	3,576	603	40	119	340	85	15	64
2003	1,272	368	3	25	182	49	3	18
2004	1,944	554	3	7	209	52	2	5
2005	469	332	9	14	106	57	5	9
2006	1,509	306	3	29	172	35	1	10
2007	2,623	332	14	61	219	35	3	15
2008	2,020	685	19	36	234	81	5	13
2009	1,866	259	14	12	217	36	3	9
2010	1,625	395	9	52	207	56	3	10
2011	1,459	492	23	6	198	45	10	3
2012	1,756	359	23	40	179	55	8	5
2013	1,686	388	11	7	187	45	7	7
2014	1,608	446	8	0	190	48	4	0
2015	2,265	422	68	50	216	61	16	11
2016	2,411	449	22	16	231	63	5	7
2017	2,734	297	15	7	239	49	5	4
2018	2,294	240	19	26	226	40	4	9
2019	1,422	188	5	12	171	31	3	2
Total	58,497	11,300	900	1,031	5,896	1,455	226	401
Average	2,250	435	35	40	227	56	9	15

Table 2.3.8. Percentage of hot spots within 3, 4, 5, and 6 miles from the northern and eastern shores of Pamlico Sound.

	June				September			
Species	3 miles	4 miles	5 miles	6 miles	3 miles	4 miles	5 miles	6 miles
Atlantic croaker	15	32	39	44	39	50	57	68
Spot	20	24	31	43	52	65	72	80
Southern flounder	35	44	52	60	59	73	82	90
Summer flounder	38	44	51	64	39	53	60	65
Weakfish	13	21	27	30	22	28	33	40
Brown shrimp	78	100	100	100	15	18	18	21
Pink shrimp	14	29	29	29	13	25	33	38
White shrimp	9	9	9	13	27	38	44	51

Table 2.3.9. Total commercial shrimp landings, trips, and participants landing shrimp from each water body within the Northern Region (Croatan and Roanoke sound), 1994-2019.

	Landings		Trips		Participants	
Year	Croatan Sound	Roanoke Sound	Croatan Sound	Roanoke Sound	Croatan Sound	Roanoke Sound
1994	7,701	14,776	102	251	16	24
1995	13,768	5,632	116	71	16	15
1996	6,590	7,896	109	183	17	29
1997	12,539	8,568	166	183	27	28
1998	1,389	188	26	9	7	3
1999	3,793	1,488	93	48	18	15
2000	40,989	7,298	490	124	56	23
2001	799	75	20	4	5	2
2002	10,010	32,080	109	390	18	58
2003	641	2,415	12	41	4	6
2004	6,856	6,646	96	142	19	23
2005	12	907	2	27	1	5
2006	2,421	642	23	20	7	3
2007	23,961	6,059	70	30	22	12
2008	4,761	2,189	32	51	12	10
2009	8,175	2,607	40	60	5	11
2010	1,075	429	18	9	3	6
2011	1,309	742	13	9	4	6
2012	4,072	713	31	21	7	3
2013	9,264	1,010	49	5	12	4
2014	2,487	289	22	11	6	3
2015	24,637	2,063	122	29	21	6
2016	23,068	15,213	60	106	16	22
2017	99,418	20,155	213	138	27	12
2018	27,507	13,685	150	152	20	19
2019	38,035	23,359	168	140	23	16
Total	375,278	177,123	2,352	2,254	389	364
Average	14,434	6,812	90	87	15	14

Table 2.3.10. Total commercial shrimp landings from each water body within the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River), 1994-2019.

Year	Bogue Sound	Core Sound	Newport River	North River	White Oak River
1994	23,344	863,245	166,380	127,327	44,995
1995	34,345	1,069,213	275,201	196,322	39,013
1996	45,689	737,829	125,092	56,511	23,825
1997	17,009	636,805	213,818	92,489	12,986
1998	41,849	547,488	71,793	27,391	23,582
1999	48,219	884,325	307,501	160,649	37,984
2000	23,875	464,916	240,583	216,045	62,164
2001	9,906	431,489	176,502	71,739	62,361
2002	31,389	783,852	292,696	186,314	137,397
2003	127,781	821,174	142,654	117,353	52,052
2004	18,624	252,813	125,039	126,873	60,283
2005	12,729	317,370	70,030	84,838	6,655
2006	70,432	260,588	199,986	258,670	58,950
2007	39,385	241,093	170,636	179,602	24,277
2008	57,928	434,900	118,998	145,782	20,282
2009	31,643	191,151	73,951	65,725	36,720
2010	34,534	119,470	91,966	55,370	15,457
2011	20,769	25,117	13,964	16,849	3,005
2012	15,117	320,249	130,512	46,086	77,767
2013	26,989	365,379	114,235	75,308	30,286
2014	3,837	219,530	91,409	23,059	10,513
2015	37,253	252,384	237,588	69,397	11,465
2016	54,536	361,792	314,397	217,710	47,499
2017	39,795	275,215	170,247	71,402	16,510
2018	50,599	209,829	86,305	61,620	5,754
2019	46,819	62,329	72,587	38,744	5,858
Total	964,396	11,149,543	4,094,071	2,789,174	927,641
Average	37,092	428,829	157,464	107,276	35,679

Table 2.3.11. Total commercial trips and participants landing shrimp from each water body within the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River), 1994-2019.

	Trips					Participants				
Year	Bogue Sound	Core Sound	Newport River	North River	White Oak River	Bogue Sound	Core Sound	Newport River	North River	White Oak River
1994	379	6,664	1,045	980	432	48	256	84	90	36
1995	363	7,366	1,033	938	265	62	290	75	157	25
1996	423	5,743	830	445	174	48	221	78	83	22
1997	259	5,627	1,350	765	187	28	213	87	93	14
1998	427	4,546	490	275	268	41	185	54	40	21
1999	257	4,696	1,313	490	177	47	184	89	67	33
2000	203	3,248	1,051	751	238	53	146	89	82	31
2001	119	3,278	921	440	352	23	146	76	68	27
2002	156	3,842	1,456	572	553	32	137	72	58	25
2003	312	3,663	893	549	387	48	143	56	61	20
2004	285	1,755	779	797	219	23	109	43	53	14
2005	183	1,343	497	465	68	13	97	33	38	8
2006	251	976	446	575	138	32	73	33	37	15
2007	174	916	543	573	132	16	68	29	44	13
2008	137	916	337	516	87	21	71	32	39	10
2009	174	903	423	361	203	12	82	24	34	13
2010	218	579	488	329	78	19	65	35	26	11
2011	115	140	98	145	34	17	37	13	14	7
2012	114	1,340	589	298	246	12	97	35	22	20
2013	179	1,442	436	315	112	21	89	31	26	17
2014	35	1,223	465	210	64	14	95	33	21	7
2015	170	835	689	197	38	20	70	40	12	3
2016	187	994	732	316	140	30	90	41	17	12
2017	166	942	476	186	35	28	93	26	19	6
2018	154	500	242	145	14	24	68	18	16	5
2019	114	170	147	99	23	17	48	12	11	1
Total	5,554	63,647	17,769	11,732	4,664	749	3,173	1,238	1,228	416
Average	214	2,448	683	451	179	29	122	48	47	16

Table 2.3.12. Total commercial shrimp landings from each water body within the Southern Region, 1994-2019. Waterbody code for Inland Waterway was split in 2002 but was still periodically recorded on old Trip Tickets through 2007.

Year	Cape Fear River	Inland Waterway	Inland Waterway (Brunswick)	Inland Waterway (Onslow)	Lockwood's Folly	Masonboro Sound	New River	Shallotte River	Stump Sound	Topsail Sound
1994	149,791	50,936	.	.	426	4,638	103,006	1,807	8,553	29,485
1995	114,261	110,409	.	.	477	1,952	274,212	1,491	25,546	59,202
1996	80,354	84,630	.	.	50	5,973	148,257	394	27,088	21,898
1997	138,424	66,675	.	.	16	5,715	244,360	2,413	29,139	22,508
1998	82,592	54,768	.	.	25	4,961	259,274	814	16,038	36,579
1999	118,742	66,506	.	.	12	2,266	271,883	176	20,522	72,561
2000	46,058	79,462	.	.	22	4,212	483,739	896	21,888	39,152
2001	17,850	51,538	.	.	1	1,514	189,084	6,123	11,795	21,888
2002	82,868	55,313	.	2,966	1	3,373	428,783	1,968	48,099	14,383
2003	101,424	47,487	18,404	31,972	1	6,561	230,381	4,333	25,010	43,141
2004	32,730	14,381	8,633	27,523	0	17,722	174,901	318	9,840	28,312
2005	46,241	13,018	16,746	45,855	0	4,745	49,506	1,352	17,202	26,535
2006	35,843	0	8,380	57,007	0	7,603	164,411	0	11,655	18,925
2007	46,124	4	11,512	25,631	2	335	151,743	0	16,497	10,657
2008	47,264	0	19,944	29,588	0	165	101,554	0	31,862	5,435
2009	44,658	0	15,873	53,465	0	125	22,552	0	20,612	24,652
2010	137,009	0	30,935	47,345	0	5,918	144,919	125	19,360	27,903
2011	79,197	0	21,042	13,421	1	66	66,584	0	2,631	25,405
2012	78,384	0	20,184	53,753	0	135	156,247	0	16,859	11,563
2013	63,635	0	6,520	88,799	0	344	135,937	0	28,334	16,203
2014	34,269	0	10,973	16,815	0	0	87,047	0	5,475	5,837
2015	33,526	0	12,766	50,143	0	0	156,882	483	17,643	15,483
2016	80,262	0	7,277	16,697	0	1,470	209,334	3,861	13,196	9,697
2017	68,323	0	16,725	12,254	0	2,408	87,073	387	10,319	5,310
2018	12,298	0	9,321	21,835	38	0	53,537	81	25,043	15,852
2019	29,326	0	2,711	4,768	0	0	106,900	712	1,784	1,547
Total	69,287	26,736	13,997	33,324	41	3,162	173,158	1,067	18,538	23,466
Average	69,287	49,652	13,997	33,324	41	3,162	173,158	1,067	18,538	23,466

Table 2.3.13. Total commercial trips landing shrimp from each water body within the Southern Region, 1994-2019. Waterbody code for Inland Waterway was split in 2002 but was still periodically recorded on old Trip Tickets through 2007.

Year	Cape Fear River	Inland Waterway	Inland Waterway (Brunswick)	Inland Waterway (Onslow)	Lockwood's Folly	Masonboro Sound	New River	Shallotte River	Stump Sound	Topsail Sound
1994	916	932	.	.	4	88	1,364	28	110	450
1995	476	1,156	.	.	7	22	2,283	21	189	660
1996	433	925	.	.	9	57	1,337	7	324	320
1997	583	819	.	.	6	111	2,344	30	315	322
1998	450	753	.	.	10	94	1,733	2	168	420
1999	447	694	.	.	6	69	2,681	3	246	641
2000	281	841	.	.	21	85	2,632	14	206	381
2001	219	719	.	.	1	39	1,626	41	180	311
2002	361	751	.	.	1	56	2,559	17	385	199
2003	323	387	203	290	1	79	1,677	37	285	351
2004	162	114	141	292	0	151	1,211	3	91	313
2005	183	63	278	341	0	36	348	7	160	216
2006	177	0	175	179	0	46	527	0	75	216
2007	362	1	183	161	1	10	628	0	163	134
2008	286	0	296	221	0	1	365	0	289	119
2009	376	0	301	454	0	1	180	0	174	242
2010	620	0	454	348	0	30	662	2	150	317
2011	479	0	371	113	1	1	349	0	46	207
2012	632	0	459	343	0	2	702	0	161	220
2013	625	0	277	682	0	3	617	0	176	212
2014	355	0	210	112	0	0	473	0	38	112
2015	331	0	235	303	0	0	386	3	139	142
2016	531	0	78	137	0	34	503	3	150	107
2017	585	0	215	92	0	19	327	6	151	71
2018	279	0	171	163	1	0	273	1	117	148
2019	456	0	74	48	0	0	226	3	47	77
Total	420	314	242	252	3	40	1,077	9	174	266
Average	409	575	220	227	3	39	1,068	9	166	252

Table 2.3.14. Total commercial participants landing shrimp from each water body within the Southern Region, 1994-2019. Waterbody code for Inland Waterway was split in 2002 but was still periodically recorded on old Trip Tickets through 2007.

Year	Cape Fear River	Inland Waterway	Inland Waterway (Brunswick)	Inland Waterway (Onslow)	Lockwood's Folly	Masonboro Sound	New River	Shallotte River	Stump Sound	Topsail Sound
1994	52	104	.	.	3	27	134	14	41	47
1995	36	132	.	.	2	12	182	5	48	64
1996	33	115	.	.	3	11	136	6	49	33
1997	40	101	.	.	2	9	158	6	42	38
1998	35	89	.	.	4	14	153	2	34	39
1999	40	139	.	.	1	14	321	3	52	69
2000	32	140	.	.	4	9	325	4	29	64
2001	26	119	.	.	1	15	197	8	32	63
2002	35	113	.	6	1	15	219	2	40	38
2003	33	76	27	41	1	18	192	4	46	47
2004	23	29	28	43	0	16	177	1	18	44
2005	19	25	37	51	0	13	93	1	31	36
2006	15	0	26	38	0	12	74	0	13	31
2007	19	1	38	23	1	7	103	0	20	30
2008	23	0	40	30	0	1	69	0	33	20
2009	22	0	43	50	0	1	38	0	32	31
2010	33	0	61	52	0	5	64	1	26	31
2011	23	0	49	18	1	1	40	0	9	22
2012	27	0	66	45	0	2	83	0	21	35
2013	27	0	36	71	0	3	68	0	28	36
2014	18	0	41	24	0	0	64	0	8	20
2015	19	0	34	45	0	0	55	2	20	24
2016	20	0	16	16	0	5	61	3	17	20
2017	24	0	26	18	0	5	42	4	20	13
2018	16	0	20	26	1	0	49	1	23	28
2019	23	0	10	9	0	0	31	2	7	9
Total	27	46	35	34	1	8	120	3	28	36
Average	43	128	43	41	2	13	171	5	43	51

Figures

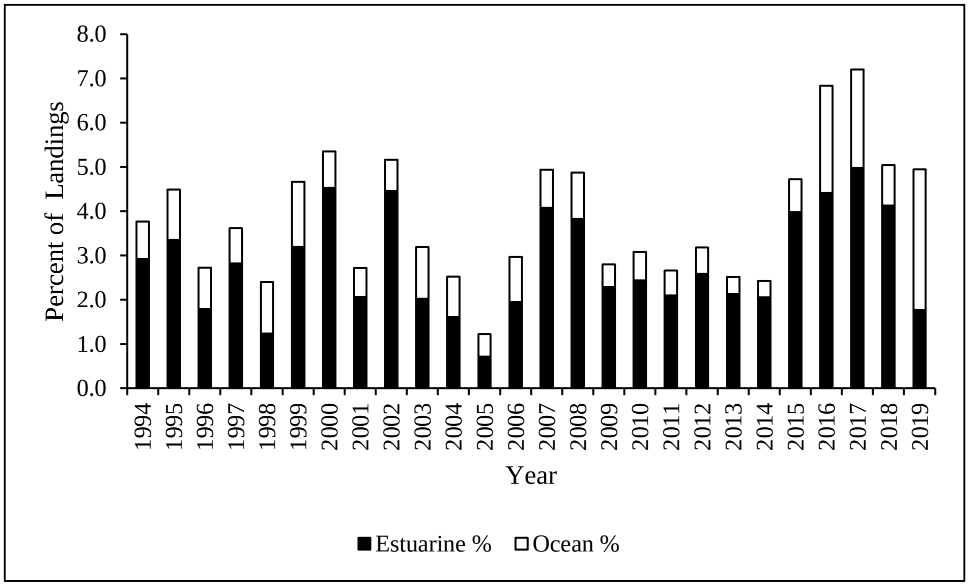

Figure 2.3.1. Percent of commercial shrimp landings reported from estuarine and ocean waters scaled to total commercial shrimp landings, 1994-2019.

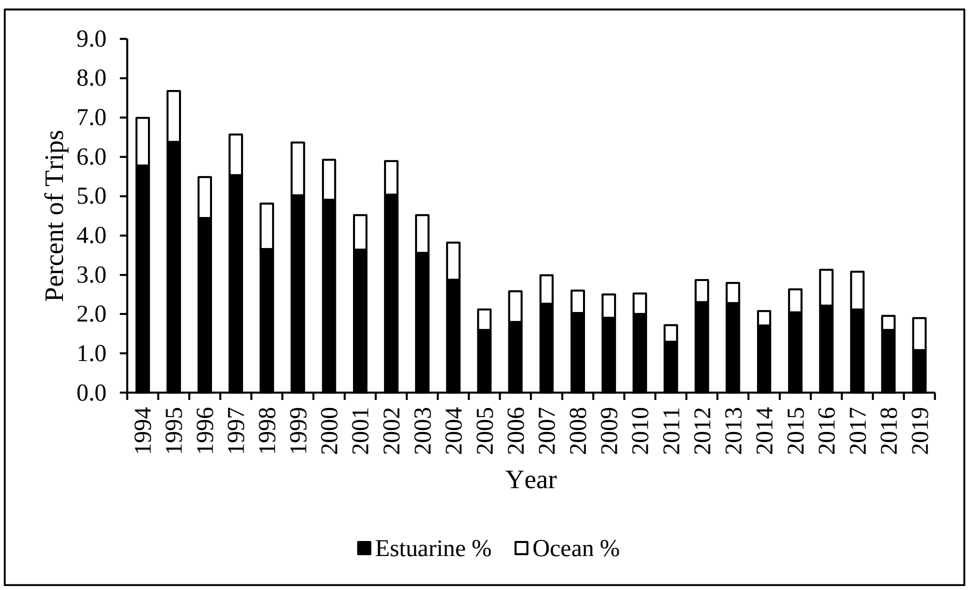

Figure 2.3.2. Percent of commercial trips landing shrimp reported from estuarine and ocean waters scaled to total commercial trips landing shrimp, 1994-2019.

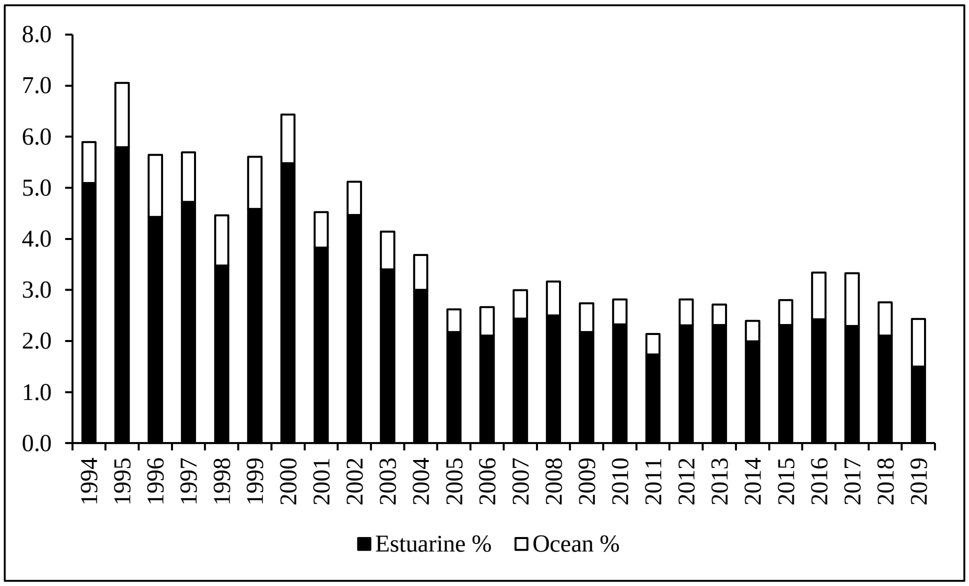

Figure 2.3.3. Percent of commercial participants landing shrimp reported from estuarine and ocean waters scaled to total commercial participants landing shrimp, 1994-2019.

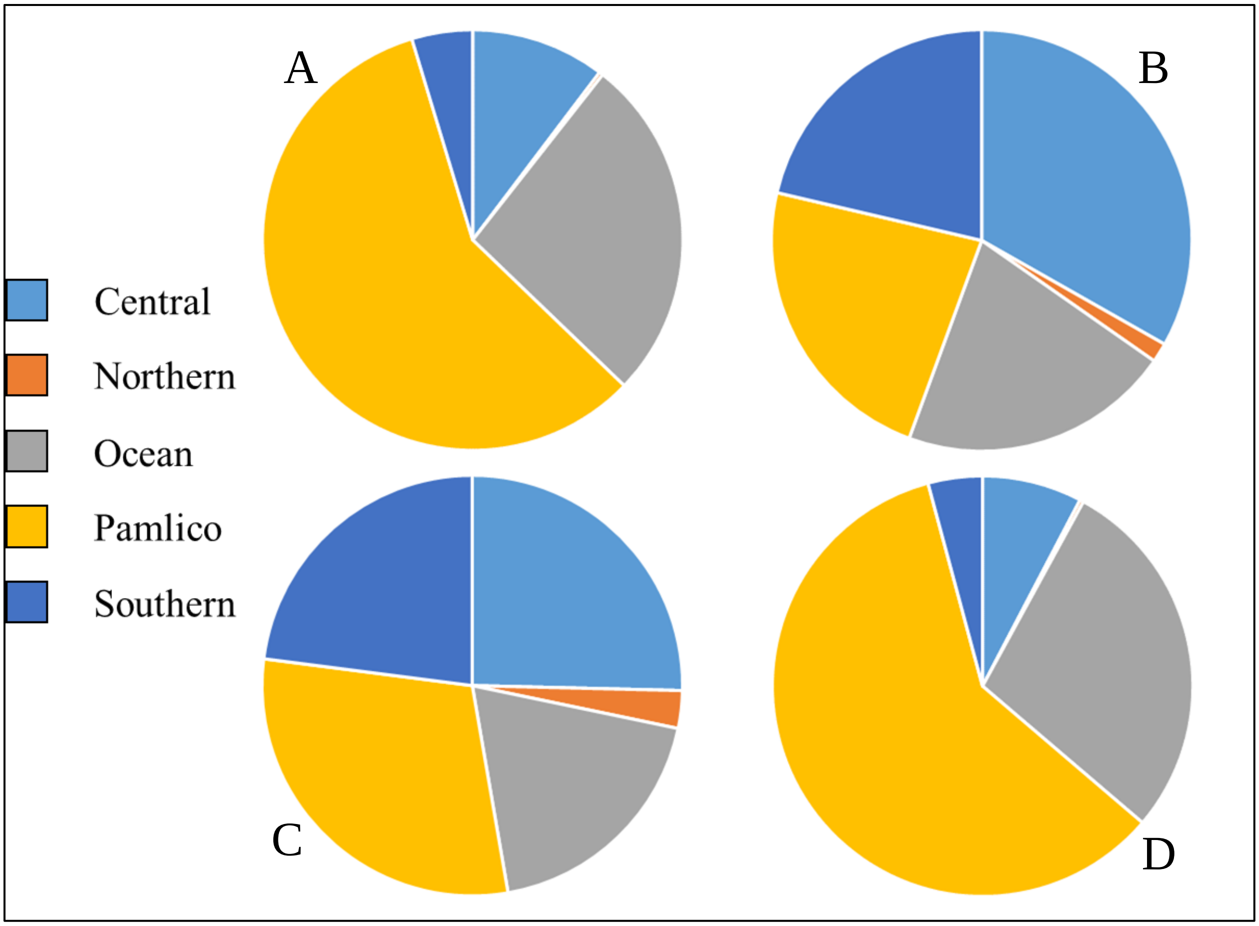

Figure 2.3.4. Percent of commercial shrimp landings (A), commercial shrimp trips (B), commercial shrimp participants (C) and value (D) in the Central, Northern, Ocean, Pamlico and Southern Regions, 1994-2019.

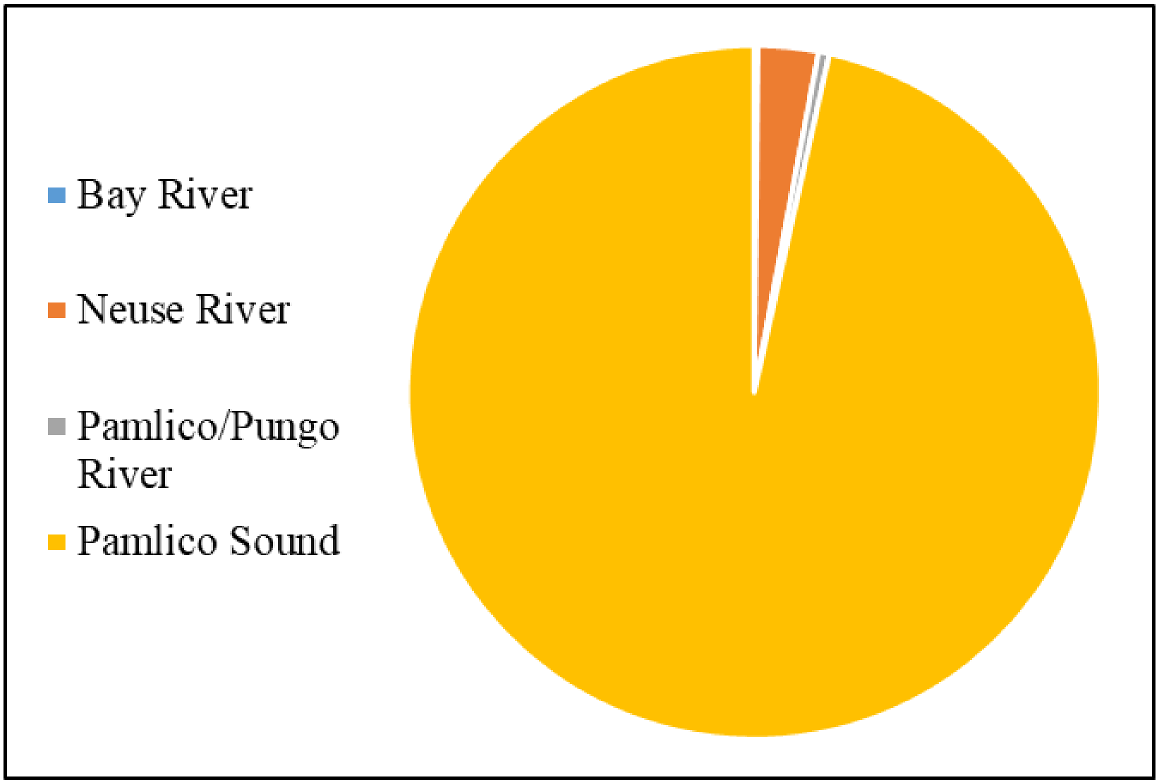

Figure 2.3.5. Percent of value by waterbody in the Pamlico Region (Pamlico Sound, Bay River, Pamlico/Pungo River).

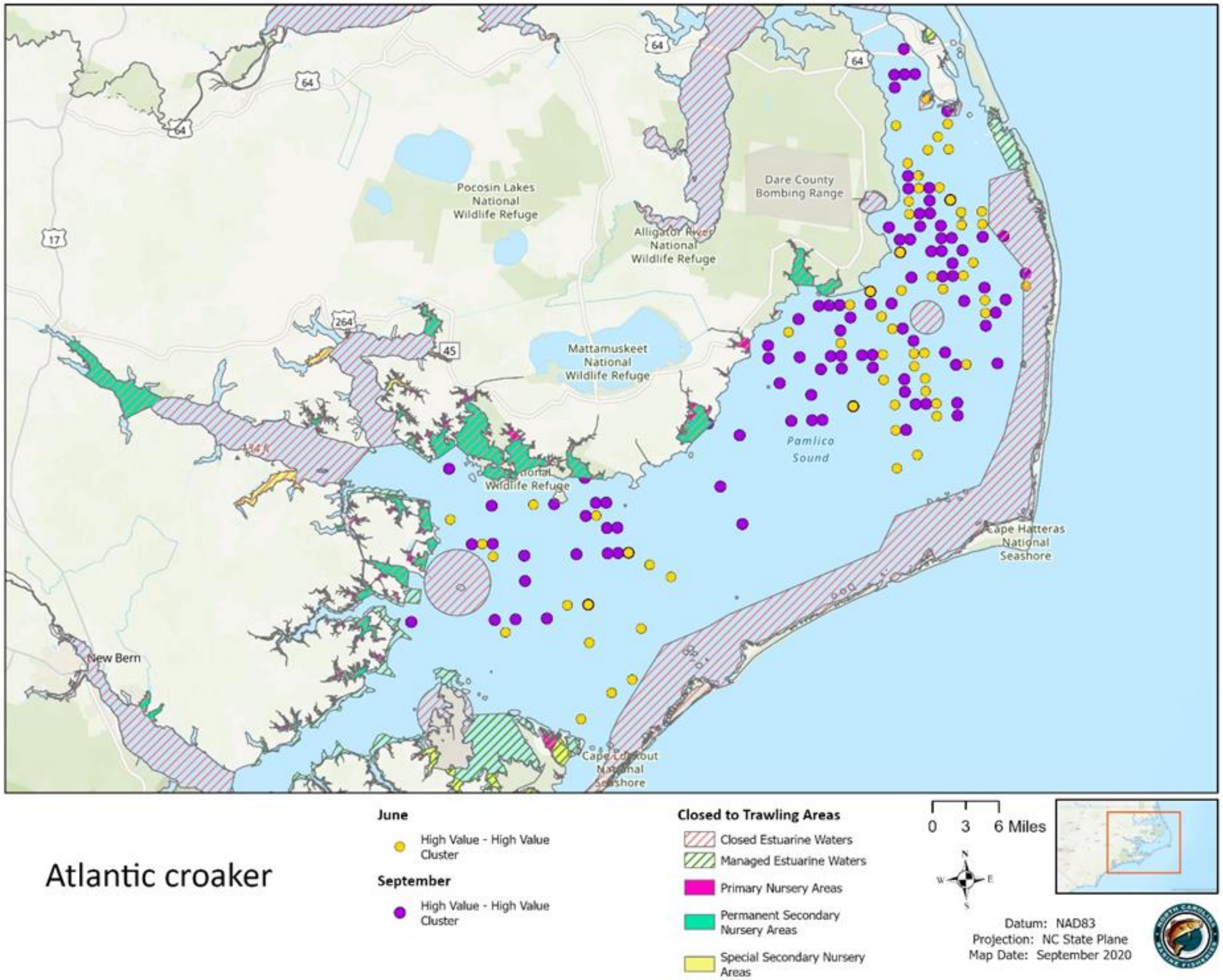

Figure 2.3.6. Hot spots of abundance for Atlantic croaker in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

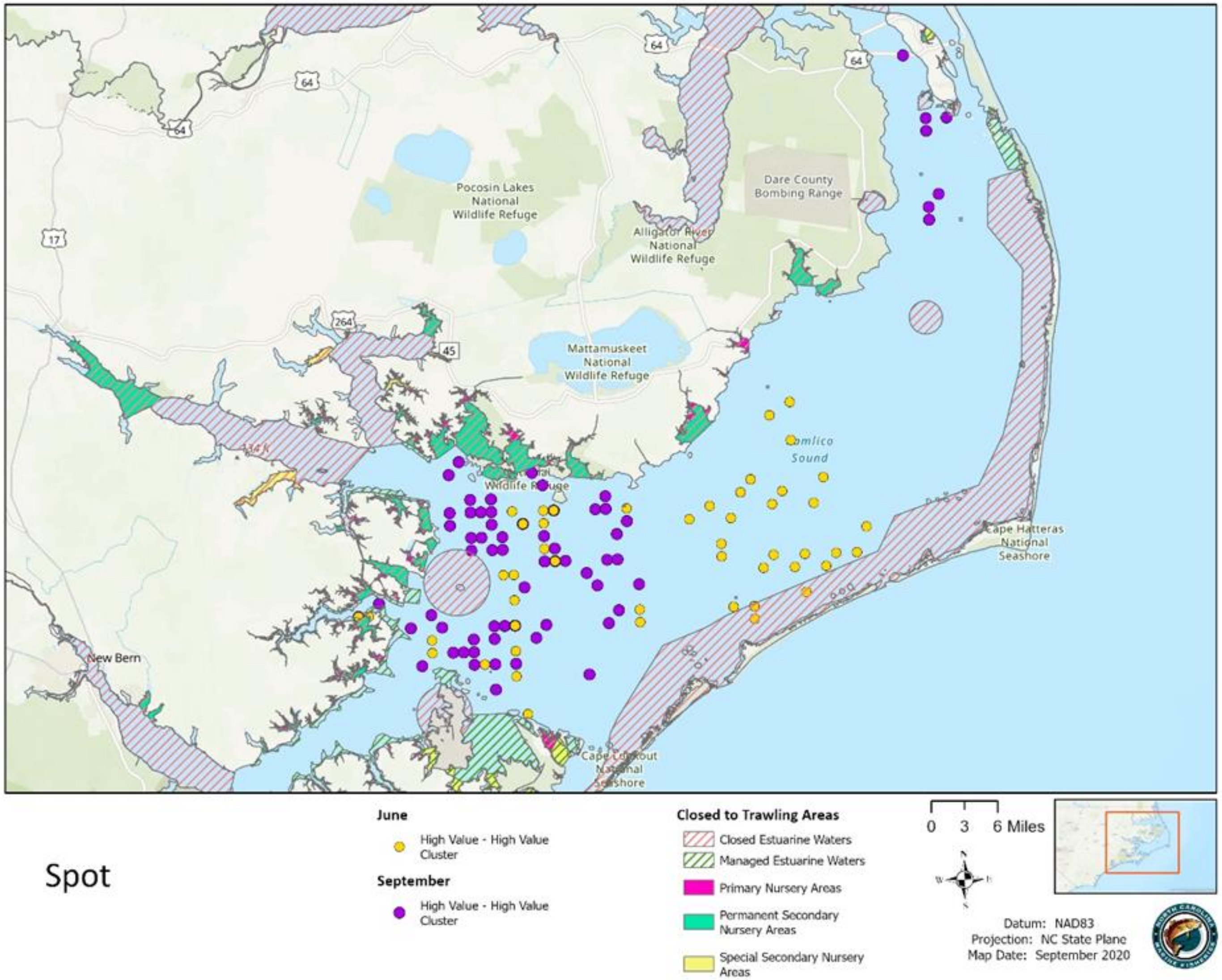

Figure 2.3.7. Hot spots of abundance for spot in Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

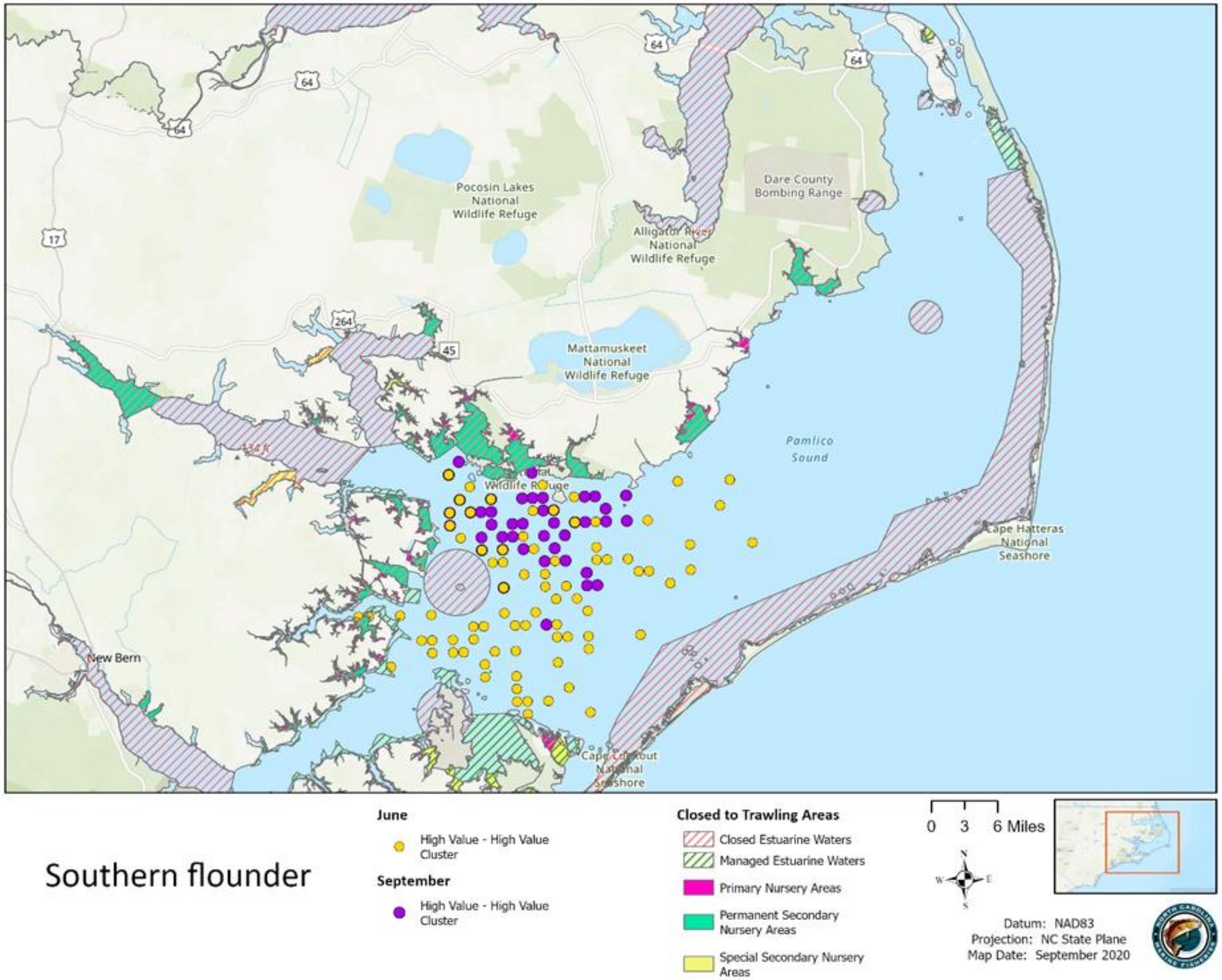

Figure 2.3.8. Hot spots of abundance for southern flounder in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

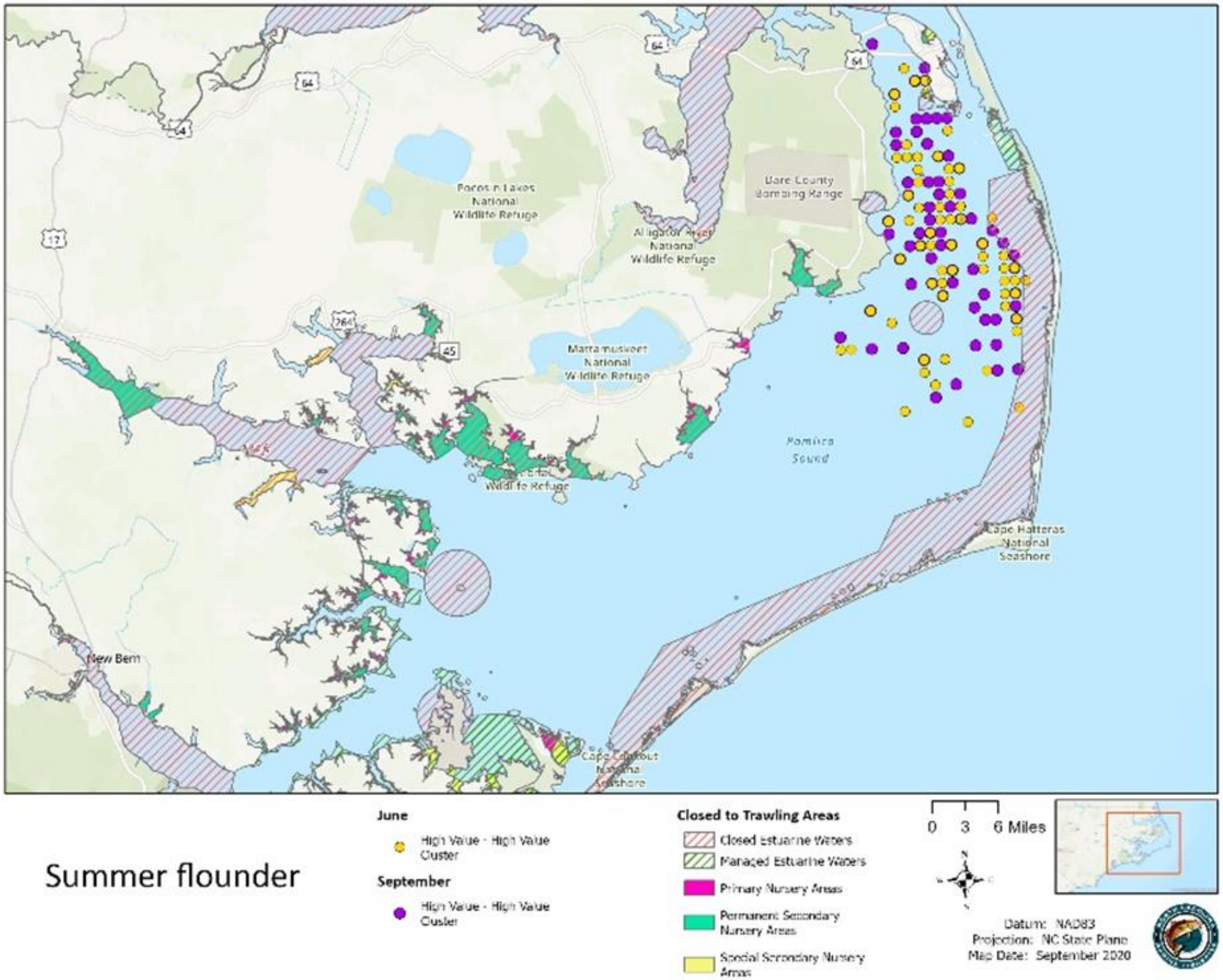

Figure 2.3.9. Hot spots of abundance for summer flounder in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

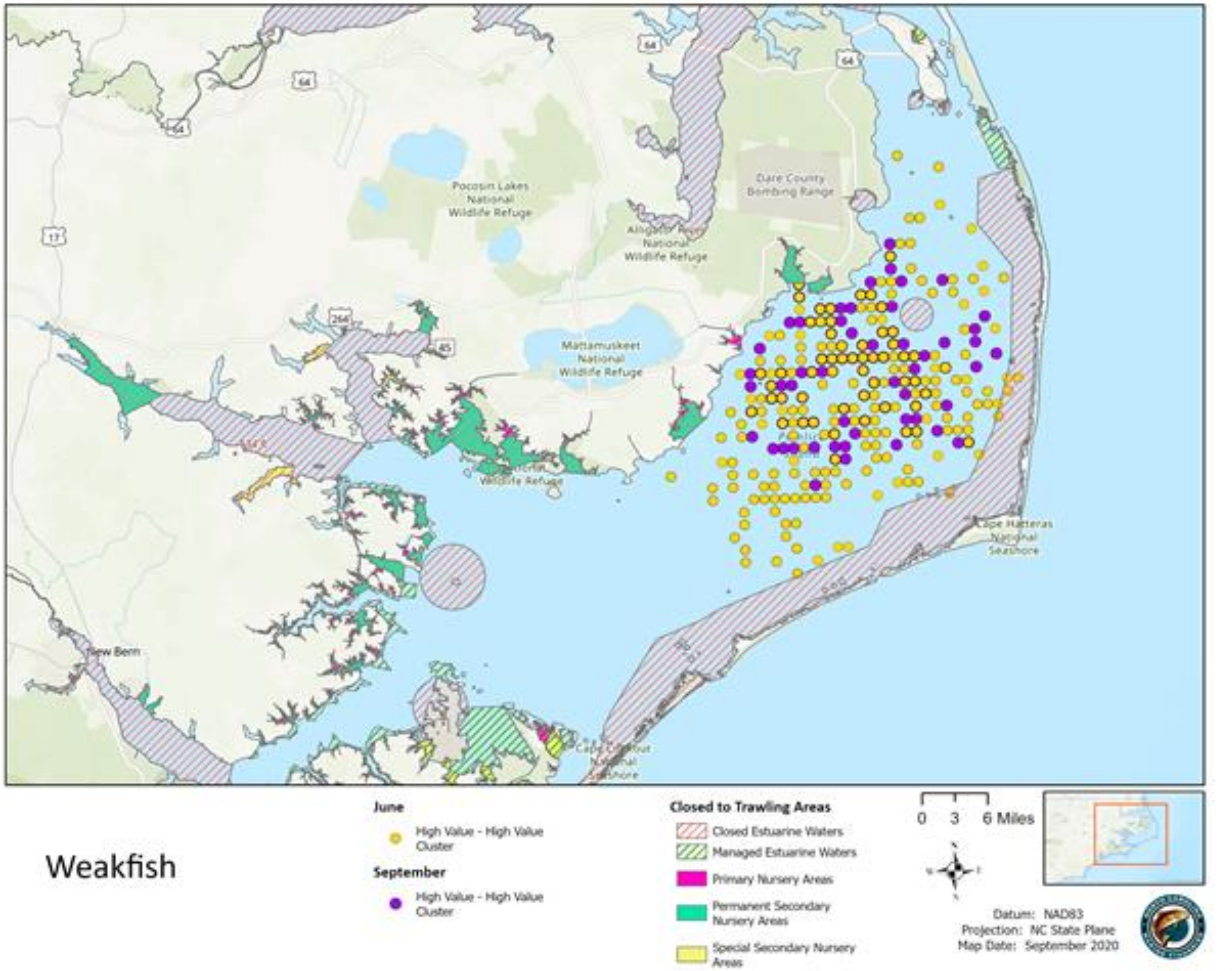

Figure 2.3.10. Hot spots of abundance for weakfish in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

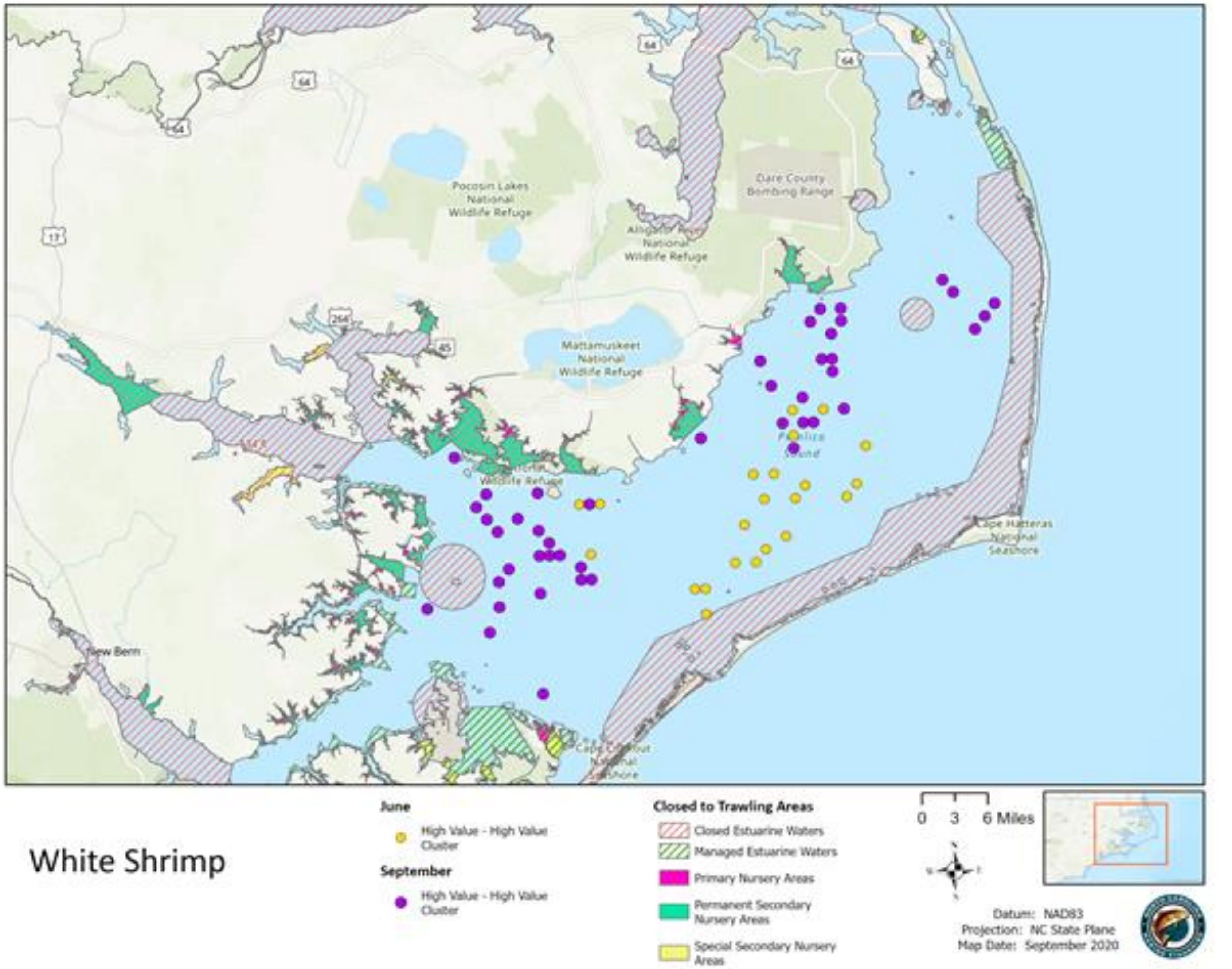

Figure 2.3.11. Hot spots of abundance for white shrimp in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

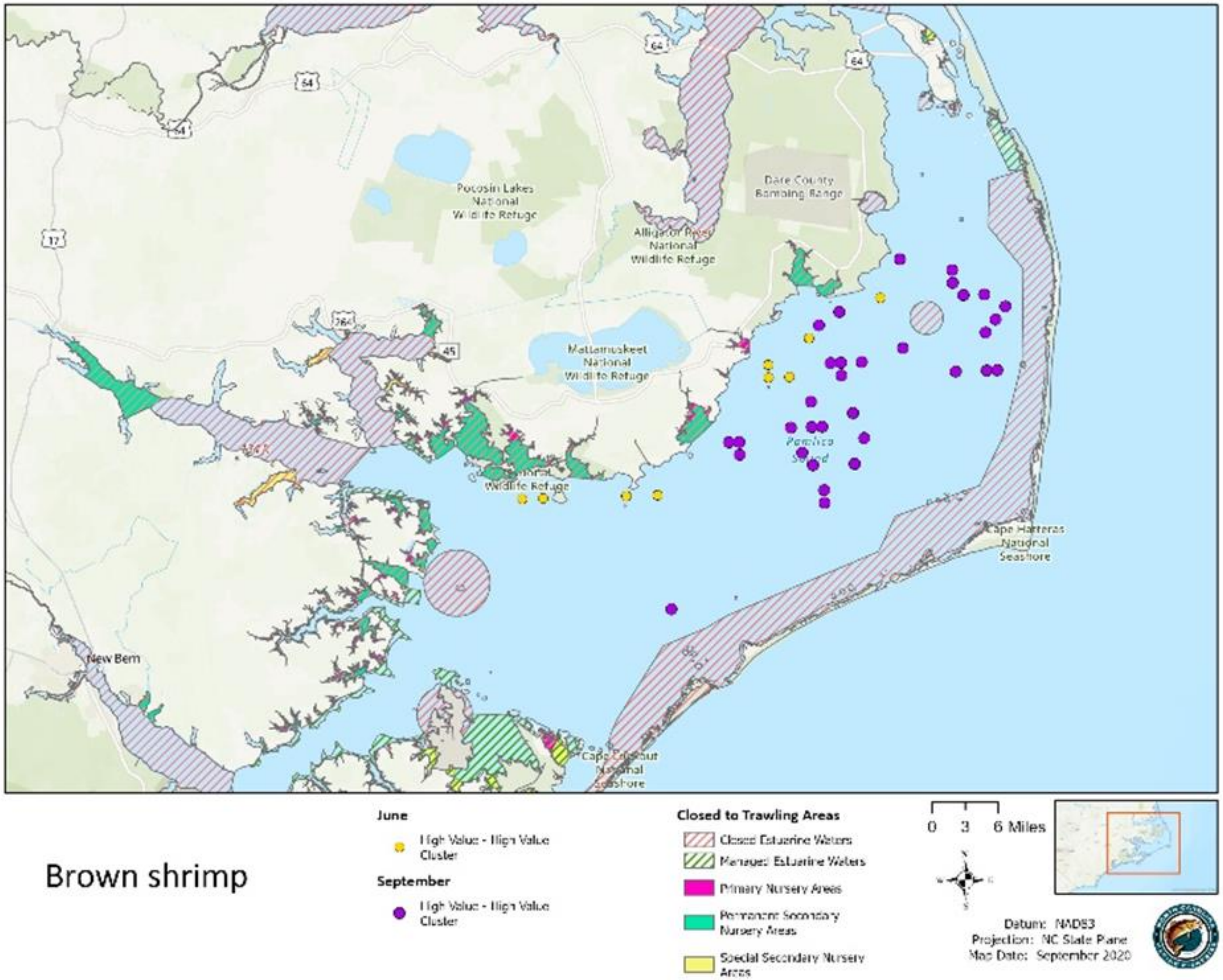

Figure 2.3.12. Hot spots of abundance for brown shrimp in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

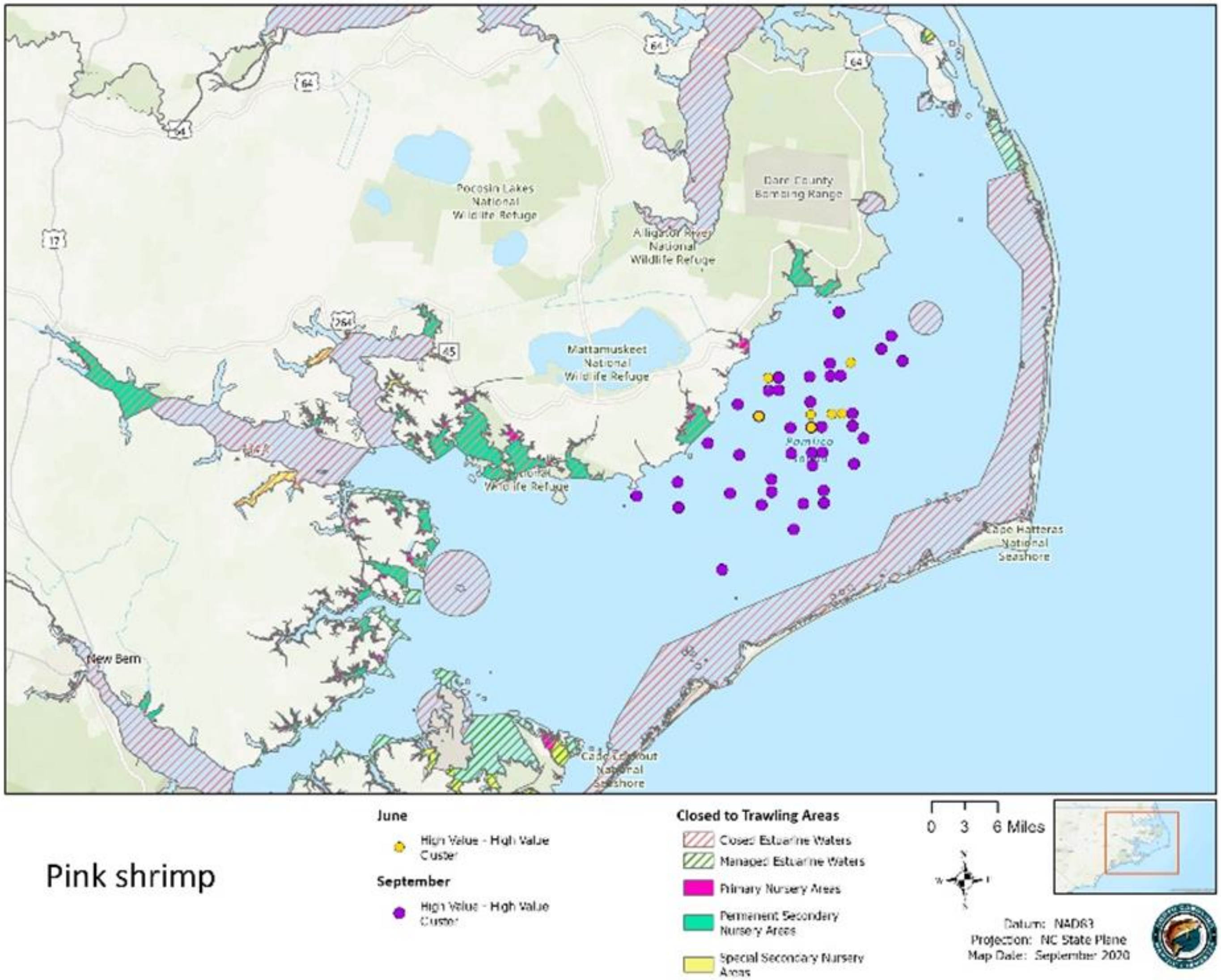

Figure 2.3.13. Hot spots of abundance for pink shrimp in the Pamlico Sound during June and September using aggregate data from Program 195, 1987-2019.

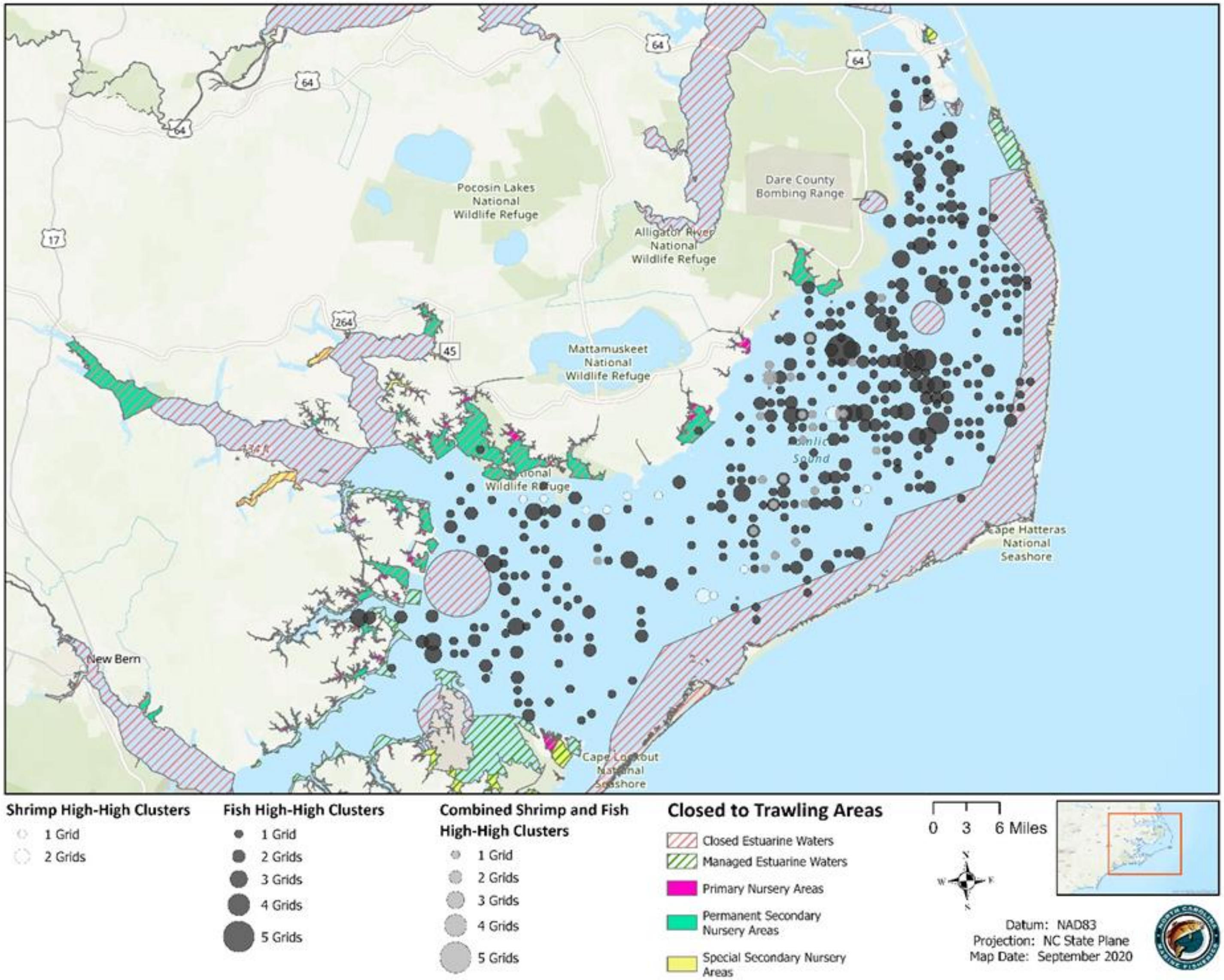

Figure 2.3.14. Frequency of hot spots for Pamlico Sound Survey sites during June using aggregate finfish and shrimp abundance data, 1987-2019.

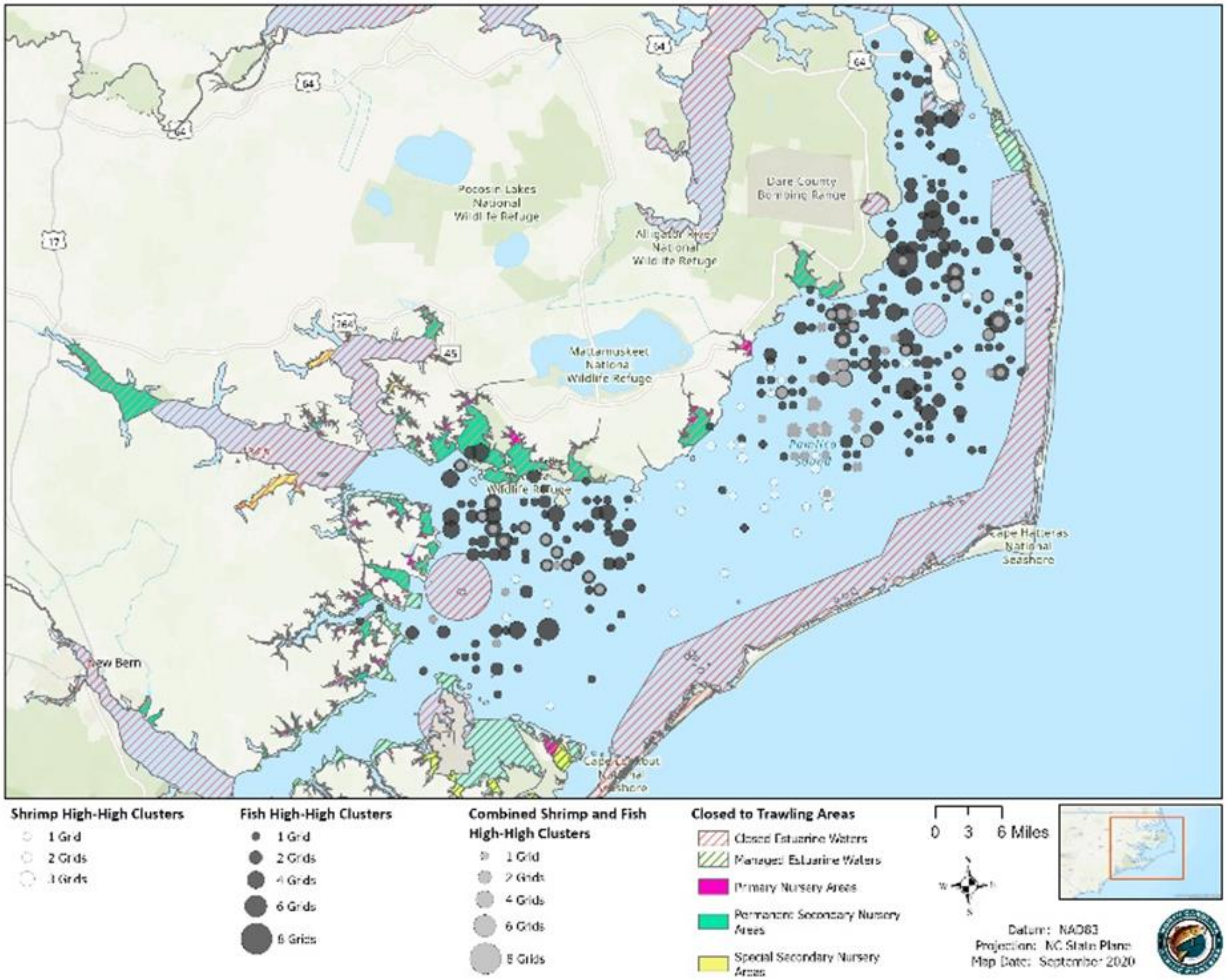

Figure 2.3.15. Frequency of hot spots for Pamlico Sound Survey sites during September using aggregate finfish and shrimp abundance data, 1987-2019.

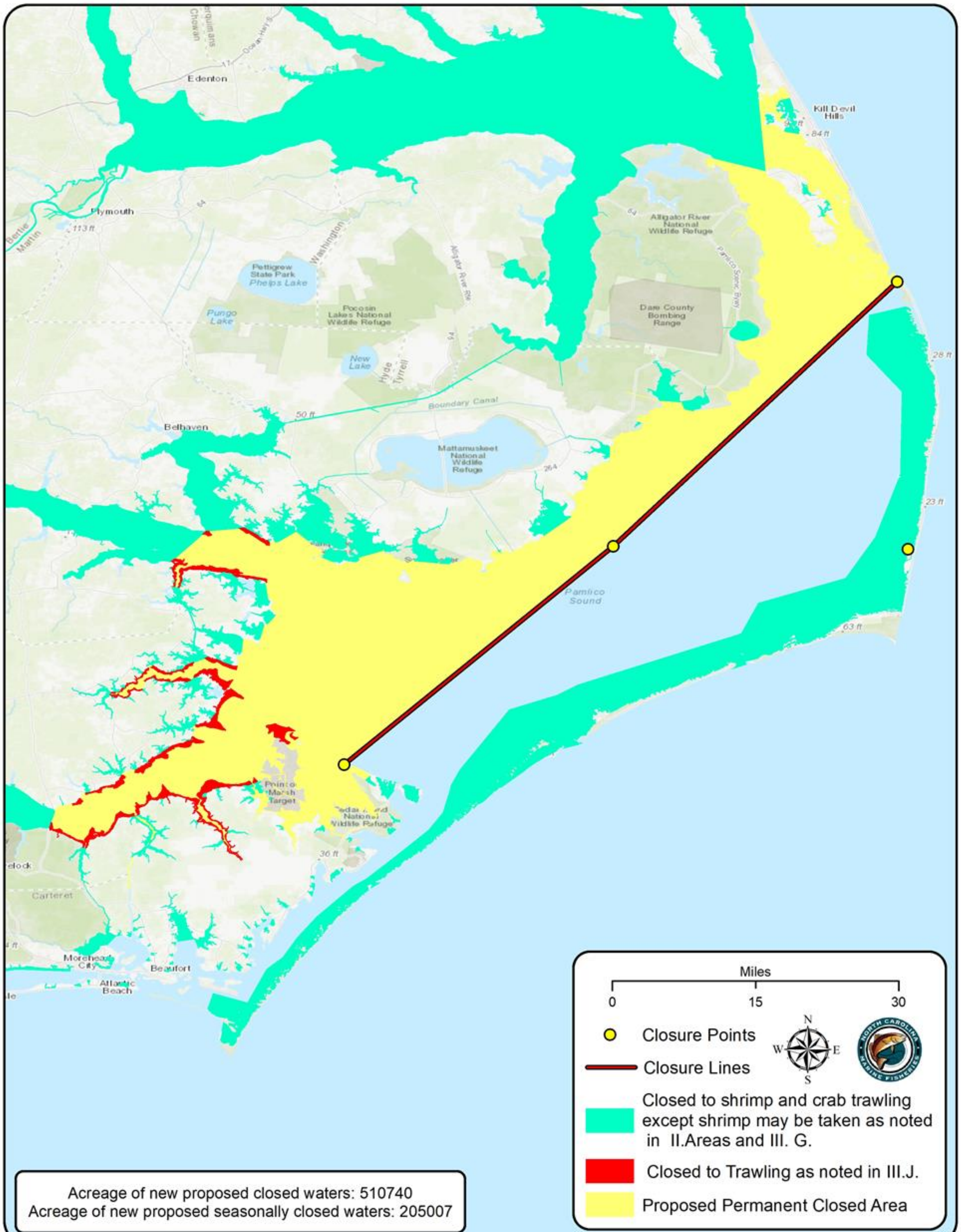

Figure 2.3.16. Example of Pamlico Sound area closure. No shrimp trawling would be permitted in internal coastal waters north and west of the red line (permanent closure).

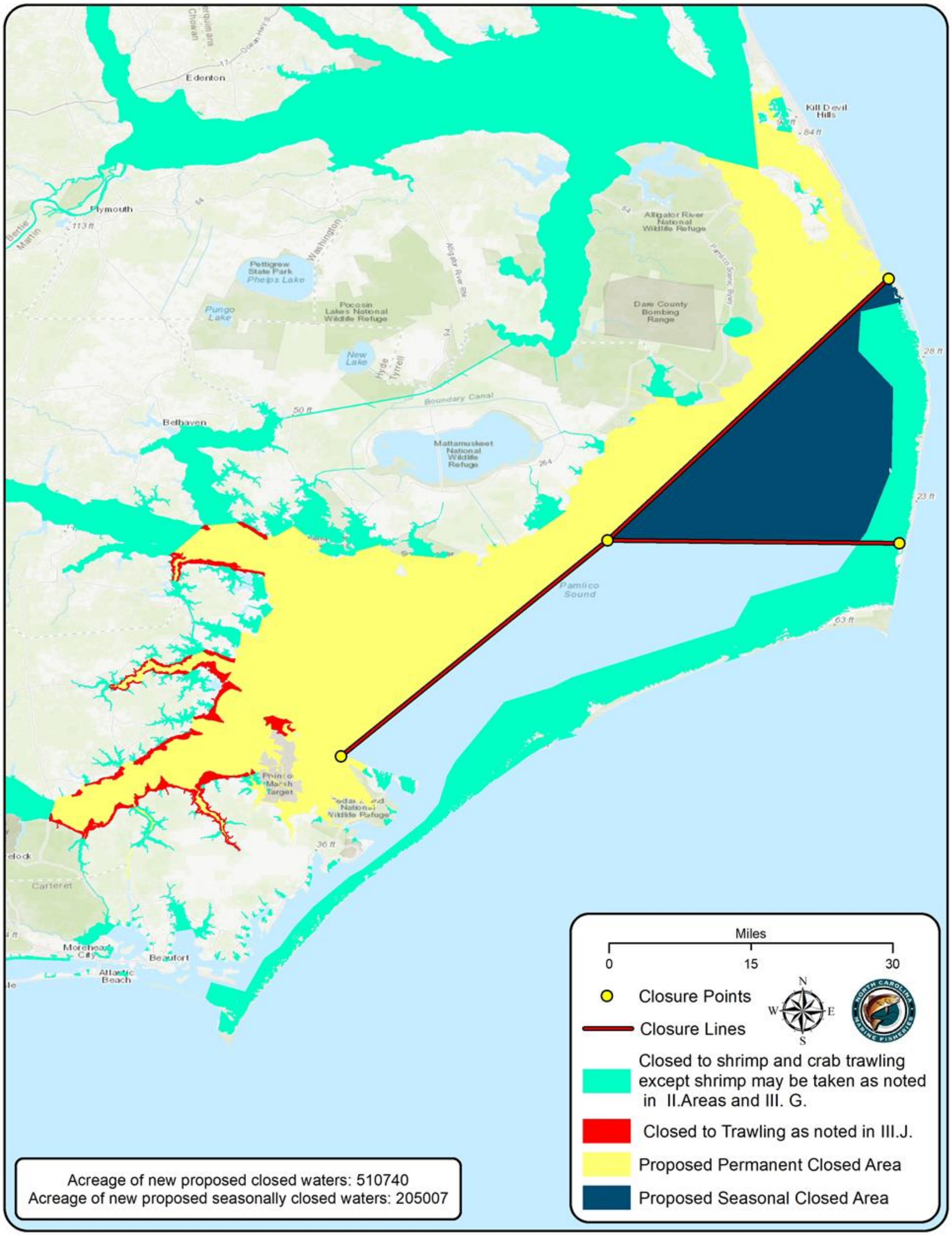

Figure 2.3.17. Example of Pamlico Sound area closure. No shrimp trawling would be permitted in internal coastal waters north and west of the larger red line (permanent closure). No shrimp trawling would be permitted north of the smaller red line from August 1 through November 30.

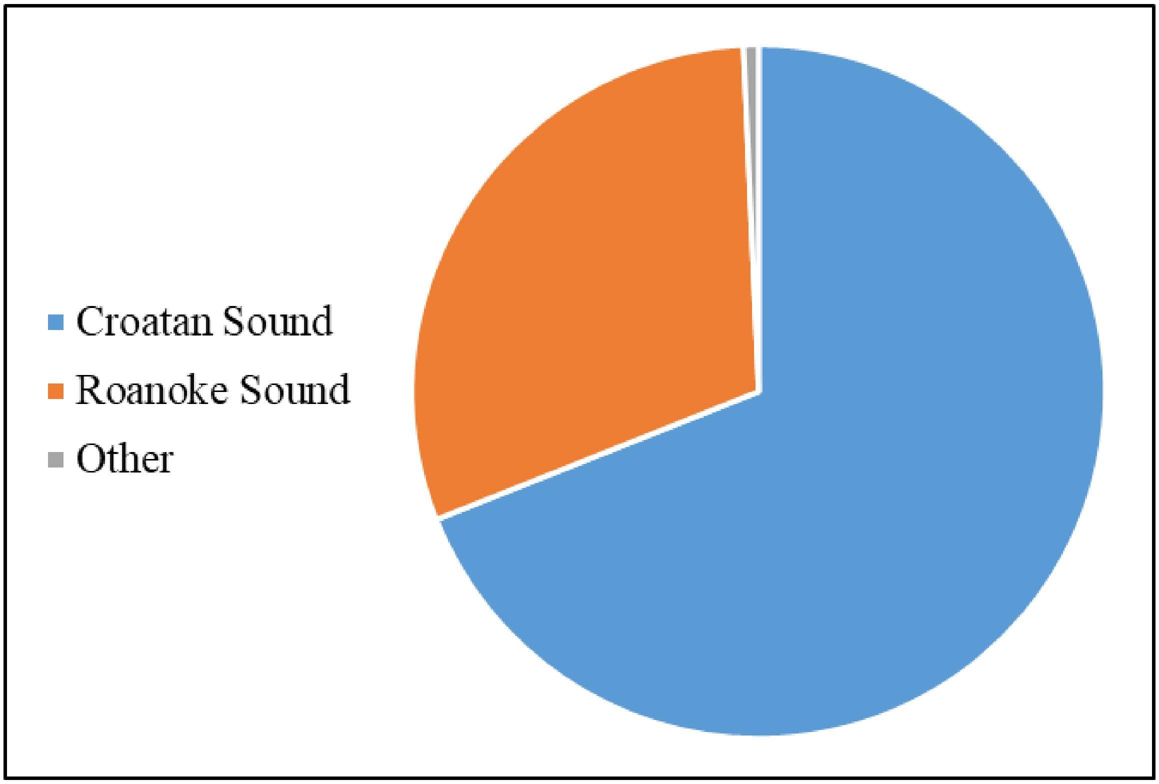

Figure 2.3.18. Percent of value by waterbody in the Northern Region (Croatan Sound, Roanoke Sound, other waterbodies). Other waterbodies include all waters north of Croatan and Roanoke sounds.

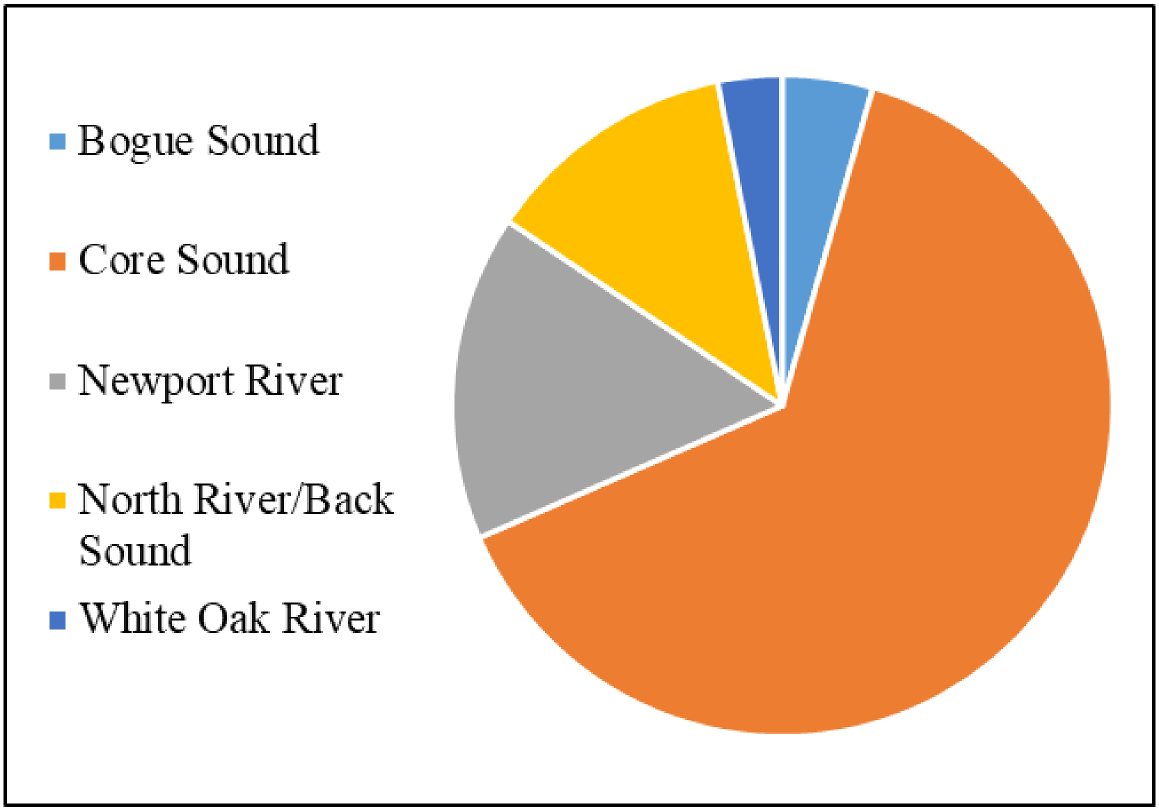

Figure 2.3.19. Percent of value by waterbody in the Central Region (Bogue Sound, Core Sound, Newport River, North River, White Oak River).

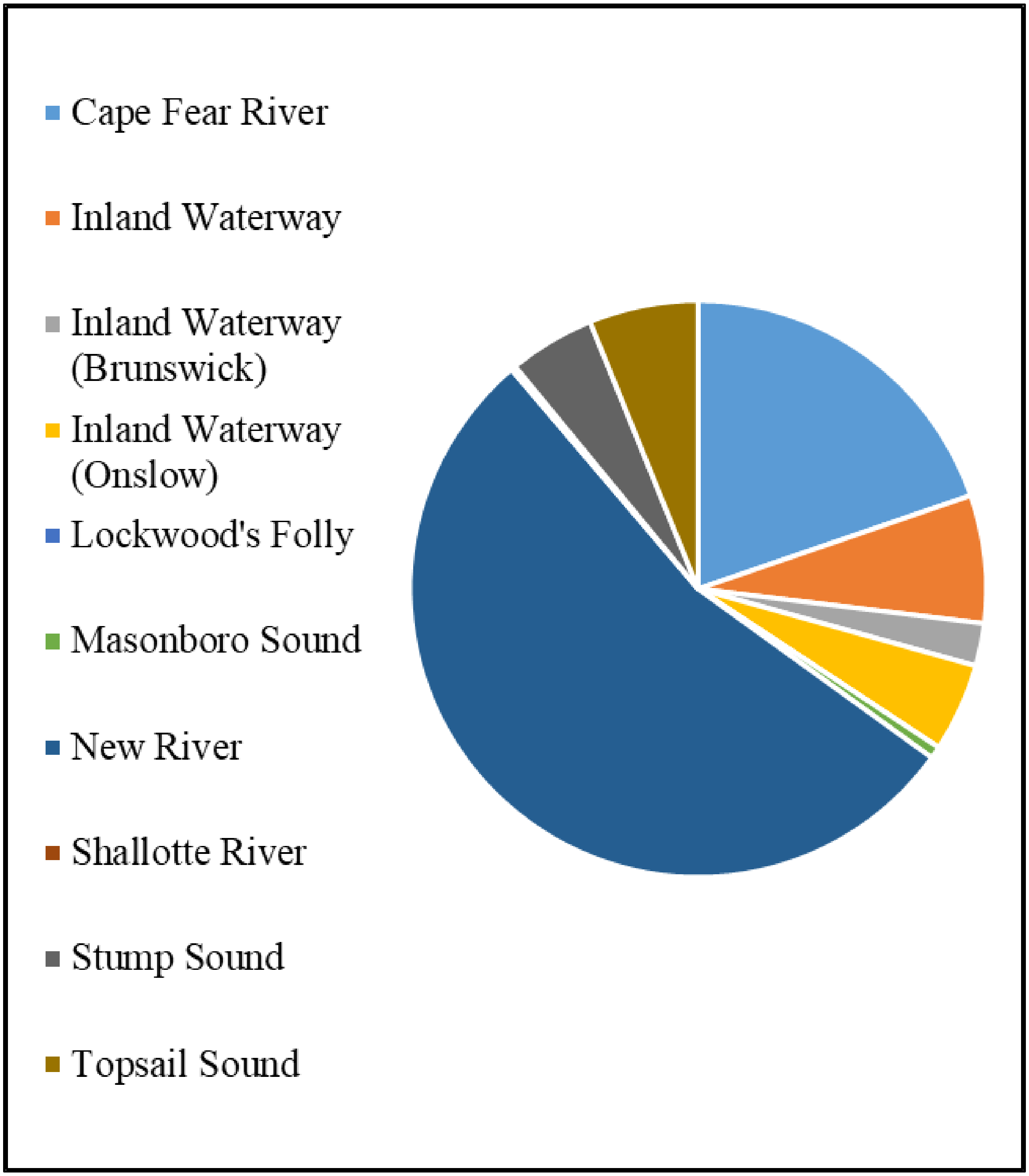

Figure 2.3.20. Percent of value by waterbody in the Southern Region (Cape Fear River, Inland Waterway, Inland Waterway Brunswick, Inland Waterway Onslow, Lockwood's Folly, Masonboro Sound). Waterbody code for Inland Waterway was split in 2002 but was still periodically recorded on old Trip Tickets through 2007.

APPENDIX 2.3.A. HOT SPOT ANALYSIS

Objective

The objective of this paper is to determine "hot spots" of abundance in the Pamlico Sound, North Carolina for shrimp and economically important species that are common as bycatch in the Pamlico Sound shrimp trawl fishery using fishery independent data collected from the Pamlico Sound Survey (Program 195).

Pamlico Sound Survey

The primary objective of the Pamlico Sound Survey is to produce fishery independent indices of abundance for important recreational and commercial fish species in Pamlico Sound, and the lower Neuse, Pamlico, and Pungo rivers (Figure 1). The survey is considered a stratified random design with strata designated by geographic location and water depth. Stations (one-minute by one-minute grid system equivalent to one square nautical mile) are randomly selected, with 54 stations sampled in June and 54 sampled in September (108 total annually).

Tow duration is 20 minutes at 2.5 knots using the R/V Carolina Coast pulling double rigged 30 ft (9.14 m) mongoose-type Falcon trawls (manufactured by Beaufort Marine Supply; Beaufort, SC) without TEDs. The R/V Carolina Coast is a 44-ft fiberglass hulled double rigged trawler owned and operated by the North Carolina Division of Marine Fisheries (NCDMF). The body of the trawl 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, chain doors that measure 4 ft by 2 ft (1.22 m X 0.061 m) and to a tongue centered on the headrope. A 60 cm "polyball" 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.

Time Series

Sampling has occurred during the middle two weeks of June and September since 1987, with some exceptions when sampling was extended into July or October because of boat maintenance or bad weather. The time series for this analysis is 1987 to 2019 with June (summer) and September (fall) analyzed separately to capture seasonal variation in "hot spot" locations. Years were combined into three-year groupings (i.e., 1987-1989, 1990-1992, etc.) to create a more spatially robust selection of sampled stations (n=162 in a year grouping for each month) while maintaining the ability to identify potential temporal variation in "hot spot" locations.

Spatial Range

The sample area covers all of Pamlico Sound and its bays, Croatan Sound up to the highway 64 Bridge, the Pamlico River up to Blounts Bay, the Pungo River up to Smith Creek, and the Neuse River up to Upper Broad Creek (Figure 1). Stations sampled are randomly selected from strata based on depth and geographic location. The seven designated strata are the Neuse River (NR), Pamlico River (PR), Pungo River (PUR), shallow and deep Pamlico Sound east of Bluff Shoal

(PSE and PDE) and shallow and deep Pamlico Sound west of Bluff Shoal (PSW and PDW). For this analysis, only stations in the Pamlico Sound strata (PSE, PDE, PSW, PDW) were considered. This was done based on the analysis objective to identify "hot spots" of abundance in Pamlico Sound to explore potential management actions in the form of areas closed to trawling and including river strata in the analysis could bias the location of these areas and most of the rivers are currently closed to bottom trawl gear.

Target Species / Assemblages

"Hot spots" of abundance for brown shrimp, white shrimp, and pink shrimp were identified. In addition, "hot spots" of abundance for economically important finfish species that are common as bycatch in the Pamlico Sound shrimp trawl fishery were identified. Species analyzed included brown shrimp (*Farfantepenaeus aztecus*), white shrimp (*Litopenaeus setiferus*), pink shrimp (*Farfantepenaeus duorarum*), Atlantic croaker (*Micropogonias undulatus*), spot (*Leiostomus xanthurus*), southern flounder (*Paralichthys lethostigma*), summer flounder (*Paralichthys dentatus*), and weakfish (*Cynoscion regalis*). Analysis was performed on each species individually because of variable spatial and temporal habitat use.

Data Processing

To examine spatial and temporal clustering of fish abundance, analysis was performed by the Optimized Outlier Analysis (OOA) and Incremental Spatial Autocorrelation (ISA) tools using ArcGIS Pro 2.5.0 (ESRI) software. The OOA tool creates a map of statistically significant hot spots, cold spots, and spatial outliers using the Anselin Local Moran's I statistic. Moran's I evaluates the overall pattern and trend of the data to determine if it is clustered, random, or dispersed (Moran 1948). In this analysis, fish and shrimp abundances from each sampling site are compared with abundances at all other sampling sites creating an index by using the Anselin Local Moran's I statistic of spatial association:

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1, j\neq i}^{n} w_{i,j}(x_j - \bar{X}) \quad (1)$$

where x_i is an attribute for feature i, $\bar{X}$ is the mean of the corresponding attribute, $w_{i,j}$ is the spatial weight between feature i and j, and:

$$S_i^2 = \frac{\sum_{j=1, j\neq i}^{n} (x_j - \bar{X})^2}{n - 1} \quad (2)$$

with n equating to the total number of features.

The z_{I_i}-score for the statistics are computed as:

$$z_{I_i} = \frac{I_i - \mathrm{E}[I_i]}{\sqrt{\mathrm{V}[I_i]}} \qquad (3)$$

where:

$$\mathrm{E}[I_i] = -\frac{\sum_{j=1, j\neq i}^{n} w_{ij}}{n-1} \qquad (4)$$

$$\mathrm{V}[I_i] = \mathrm{E}[I_i^2] - \mathrm{E}[I_i]^2 \qquad (5)$$

A positive value for I indicates that a site has neighboring sites with similarly high or low abundances; these sites will be labeled either a high or low value cluster. A negative value for I indicates that a site has a neighboring site with dissimilar values; this site is labeled an outlier. The local Moran's I is a relative measure and can only be interpreted within the context of its computed z-score or p-value. When the p-value for the site is $p<0.05$, the cluster or outlier to be considered statistically significant.

Local statistics are calculated on the basis of a defined distance threshold or neighborhood and the results for locations containing similar neighbors are likely to be correlated (Anselin 1995, Getis and Ord 1996). For this analysis, the Incremental Spatial Autocorrelation tool was used to compute Moran's I statistics, z-scores and p-values (Table 1.) Each of the eight finfish and three shrimp species in this analysis exhibit different spatial and temporal differences between spring and fall. Therefore, it was necessary to find an appropriate distance threshold where spatial autocorrelation is maximized for each species (Table 2; ESRI Events 2017).

Though the OOA tool will determine the distance band, the ISA tool was used to confirm the appropriate distance thresholds used in this analysis. The ISA tool measures spatial autocorrelation for a series of distances and optionally creates a line graph of those distances and their corresponding z-scores. ISA compares the abundance values at one site with the values at all other sites creating an index by using the following equation:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\left(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\right)\left(\sum\left(x_i - \bar{x}\right)^2\right)}$$

Where:

n = the total number of sites

$\bar{x}$ = the global mean value

x_i = the abundance value at a particular site

x_j = the abundance value at another site

w_{ij} = the weight applied to the comparison between site *i* and site *j*, which is the inverse distance between the two sites (1/d*ij*).

The statistical significance for Moran's I can be calculated using z-score methods. Based on the expected values (E[I]) for a random pattern and the variances (VAR[I]), the standardized z-score can be mathematically represented as follows:

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}}$$

The z-scores reflect the intensity of spatial clustering, and statistically significant z-score peaks indicate the distances where clustering is most pronounced (Figure 2). These peak distances are the most appropriate values to use for the distance band parameter in the various clustering and hot spot analysis tools in ArcGIS. When more than one statistically significant peak is present, the appropriate distance is often the first statistically significant peak encountered.

For this analysis, the OOA tool was run with each distance where a peak z-score occurred. The output for each distance threshold was examined for the number of significant clusters, number of locational outliers, and percent of sites with less than eight neighbors (Table 3). Cluster and hot spot analyses have three caveats in determining the appropriate distance threshold: all features should have at least one neighbor, no feature should have all other features as neighbors, and the most appropriate distance will allow a feature to have at least eight neighbors (ESRI).

The OOA tool creates a map showing statistically significant clusters or outliers with 95% confidence level. Sites with high abundance values surrounded by other sites with high abundance values are labeled as high-high (HH) clusters; sites with low abundance values surrounded by other sites with low abundance values are labeled low-low (LL) clusters. Outlier sites, in which a site with a high abundance value is surrounded primarily by sites with low abundance values, are labeled as a high-low (HL) outlier; or a low abundance value primarily surrounded by sites with high abundance values are labeled a low-high (LH) outlier (Fig. 3).

Results and Discussion

This analysis used Cluster and Outlier Analysis to identify high abundance clusters or, hot spots, for five species of finfish and three species and examines temporal and spatial differences in distribution. The OOA tool calculates a z-score to indicate the intensity of clustering at a distance where the clustering is most pronounced. All species analyzed seemed to have hot spots located near the west side of the Pamlico Sound and at the mouths of the Pamlico and Neuse Rivers. However, each of the eight finfish and shrimp species exhibited different distributions of hot spots and showed temporal differences between spring and fall. Atlantic croaker and spot are the two most abundant species captured in the Pamlico Sound Survey (Paris et al. 2020a, 2020b) and the resulting hot spots for both species were the most widely distributed of the five finfish species (Figures 2.3.6 and 2.3.7). The resulting z-scores and distance thresholds indicated similar clustering between the two species. Atlantic croaker had the greatest number of hot spots in

September, n = 115; 26%, and third highest in June, n = 75; 14%, while spot had the least number of hot spots in June, n = 51; 9% and second least in September n = 75; 17% (Table 4). The distance threshold for both species in September was 25,600 m and z – scores were similar, Atlantic croaker z = 12.29 and spot, z = 10.29. In June, the distance threshold for Atlantic croaker was larger and had a greater z-score, 30,400 m and z = 9.53, compared to spot, 25,600 m, z = 4.88. Clustering for Atlantic croaker was stronger in the northern portion of the sound extending into the Croatan Sound during September, compared to June where hot spots occurred along the south west portion of the sound. Spot hot spots in June were less concentrated at the mouth of the rivers, extending further east compared to Atlantic croaker and had much less clustering in the north.

Southern flounder showed strong clustering in the southern portion of the sound at the mouths of the Pamlico and Neuse Rivers in both June and September (Figure 2.3.7). More hot spots were identified in June, (n = 97; 18%) compared to September (n = 49; 11%). Hot spots in September were clustered at the mouth of the Pamlico River, compared to June where hot spots were concentered at the mouth of the Pamlico and Neuse rivers extending east towards the center of the sound. The more concentrated clustering in September can also be identified by the lower distance threshold, 14,400 m compared to a distance threshold of 38,400 m in June.

Summer flounder and weakfish had the least temporal differences in hot spot distribution. The hot spots for summer flounder were all located in the northern Pamlico Sound and Croatan Sound in both June and September (Figure 2.3.9), though more hot spots were identified in September. Weakfish hot spots in September are more concentrated in the center of Pamlico Sound compared to June (Figure 2.3.10). The distance threshold for weakfish for both seasons was 25,600 m and with nearly identical z-scores for both seasons (z = 12.52 and z = 12.53) indicating similarly intense clustering with the same spatial scope for both seasons. Weakfish had the greatest number of hot spots, (n = 258; 47%, n = 116; 27%) while summer flounder had the second greatest number of hot spots in September (n = 80; 18%), and the fourth highest number in June (n = 72; 13%). Summer flounder was shown to have close to no temporal difference in hot spot distribution. The number of hot spots was very similar in both seasons (n = 72; 13% and n = 80; 18%) and had identical distance threshold and z-scores (25,600 m and z = 11.62) indicating the same level of clustering.

All three shrimp species had fewer hot spots in June compared to September. In June, shrimp utilize nearshore habitats before moving out to the ocean in the fall. White shrimp hot spots were more prevalent in September (n = 45; 38%) compared to June (n = 23; 59%) and hot spots were distributed throughout the center of the sound in June and closer to the shoreline in September (Figure 2.3.11). Though white shrimp hot spots were seemingly separated in two different regions, the clustering was strong in those areas. The white shrimp distance threshold in September was lower and the z-score higher (12,800 m; z = 18.27) compared to June (22,400 m; z = 3.98). Brown shrimp (Figure 2.3.12) had the fewest hot spots of the shrimp species in September (n = 9; 23%) and the second fewest in June (n = 33; 28%). Hot spots were located close to shore the norther shore of the sound in June and had a low z–score (z = 4.30) indicating low intensity clustering. In September, brown shrimp moved toward the center of the sound with a low z-score, z = 3.39. Pink shrimp hot spots were concentrated in the center of the sound in both seasons (Figure 2.3.13). Pink shrimp had the fewest hot spots in June (n = 7; 18%) increasing in September (n = 40; 34%).

Clustering in June was not as strong (14,400 m; z = 6.72) compared to September (14,400 m; z = 11.08).

This analysis contained data from eight separate species with varied life histories and distributions over a 32-year time series. Examining each species individually was necessary to discern species specific temporal and spatial trends. When all species' hot spots were plotted on one map no clear pattern spatial pattern emerges. The map of June hot spot frequency shows distribution of finfish and shrimp throughout the sound (Figure 2.3.14). There is a concentration of high value clusters in the northern part of the sound between Hyde County and Cape Hatteras, likely because of weakfish hot spots in this region. The map of September hot spot frequency shows a distinct temporal shift in distribution from June. Finfish are concentrated at the mouths of the Pamlico and Neuse Rivers and in the northern portion of Pamlico Sound into Croatan Sound. Shrimp hot spots were found in the center of Pamlico Sound, but not in large numbers.

Identifying hot spots for commercially important bycatch species commonly found in the North Carolina shrimp trawl fishery can help managers determine regulations to protect areas that are important for these species. Examining hot spots for shrimp and bycatch species together helps identify area where finfish may not be abundance and shrimp may be abundant, therefore allowing the shrimp trawling in these areas may effectively reduce bycatch while allowing shrimp harvest to occur. This analysis does indicate a strong temporal shifts in distribution for some finfish and shrimp species, and provides evidence for mangers to propose seasonal regulations to protect important bycatch species.

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Tables

Table 2.3.A.1. Output from the Incremental Spatial Autocorrelation Tool (ISA) from weakfish in June.

Year	Distance (ft)	Moran's I	z-score	p-value
1987_1989	20,800	0.25	12.62	0.00
1990_1992	14,400	0.30	10.23	0.00
1993_1995	33,600	0.14	11.93	0.00
1996_1998	28,800	0.02	2.29	0.00
1999_2001	33,600	0.15	12.52	0.02
2002_2004	17,600	0.15	7.21	0.00
2005_2007	25,600	0.11	7.39	0.00
2008_2010	36,800	0.01	2.26	0.02
2011_2013	24,000	0.17	10.20	0.00
2014_2016	14,400	0.31	11.56	0.00
2017_2019	14,400	0.22	7.63	0.00

Table 2.3.A.2. Distance thresholds and z-scores for the five finfish and three shrimp species used in this analysis.

	June		September	
Species	Distance (m)	z-score	Distance (m)	z-score
Atlantic croaker	30,400	9.53	25,600	12.29
southern flounder	38,400	13.91	14,400	11.06
spot	25,600	4.88	25,600	10.29
summer flounder	25,600	11.62	25,600	11.62
weakfish	33,600	12.52	19,200	12.53
brown shrimp	16,000	4.30	20,800	3.39
pink shrimp	14,400	6.72	14,400	11.08
white shrimp	22,400	3.98	12,800	18.27

Table 2.3.A.3. Output from Optimized Outlier Analysis tool for identified peak z-scores with ISA, with June weakfish data.

Year	Distance (ft)	Features (N)	Locational outliers	Significant Clusters	High-value Outliers	Low-value Outliers	Low Value Clusters	High Value Clusters	% of Features Have Less Than 8 Neighbors
1993_1995	33,600	114	0	100	4	24	40	32	0
1999_2001	33,600	118	1	106	3	26	40	37	0
2014_2016	14,400	119	2	48	2	14	12	20	8.4

Table 2.3.A.4. Total amount of Hot Spots generated by species.

	June		September	
Species	Total	% of Total	Total	% of Total
Atlantic croaker	75	14	115	26
southern flounder	97	18	49	11
spot	51	9	75	17
summer flounder	72	13	80	18
weakfish	258	47	116	27
Finfish Total	553	100	435	100
brown shrimp	9	23	33	28
pink shrimp	7	18	40	34
white shrimp	23	59	45	38
Shrimp Total	39	100	118	100

Table 2.3.A.5. Distance thresholds and Z-scores produced by the Optimized Outlier Analysis tool for each finfish and shrimp species.

	June		September	
Species	Distance (m)	z-score	Distance (m)	z-score
Atlantic croaker	30,400	9.53	25,600	12.29
southern flounder	38,400	13.91	14,400	11.06
spot	25,600	4.88	25,600	10.29
summer flounder	25,600	11.62	25,600	11.62
weakfish	33,600	12.52	19,200	12.53
brown shrimp	16,000	4.30	20,800	3.39
pink shrimp	14,400	6.72	14,400	11.08
white shrimp	22,400	3.98	12,800	18.27

Figures

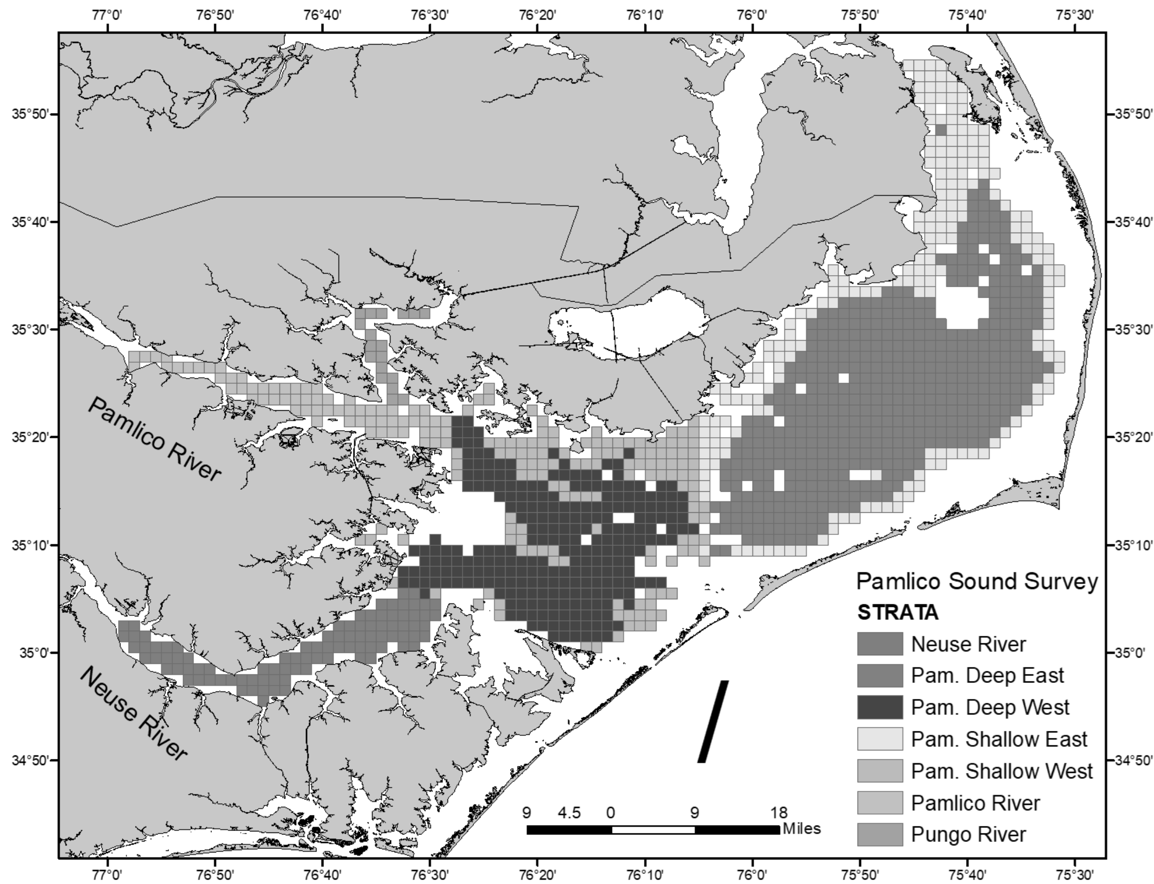


Figure 2.3.A.1. Pamlico Sound Survey sampling grids by strata.

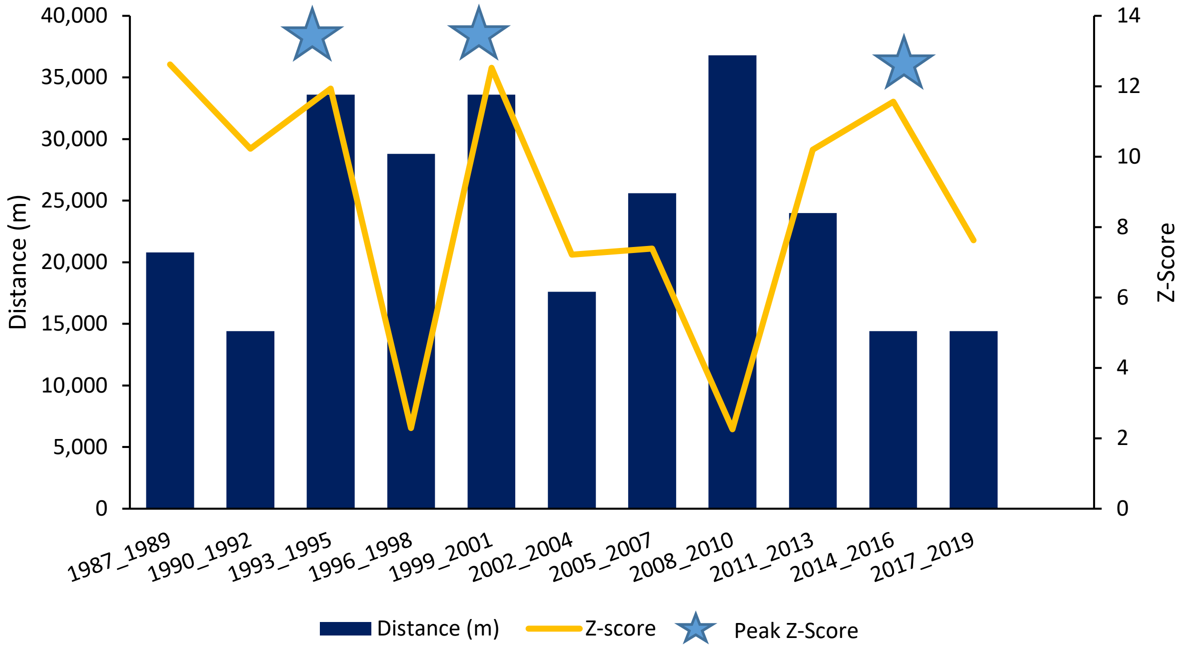


Figure 2.3.A.2. Results from ISA on June weakfish survey data, showing the highest (peak) z-score values using a 33,600 m distance threshold. z-score peaks reflect distances where clustering is most pronounced.

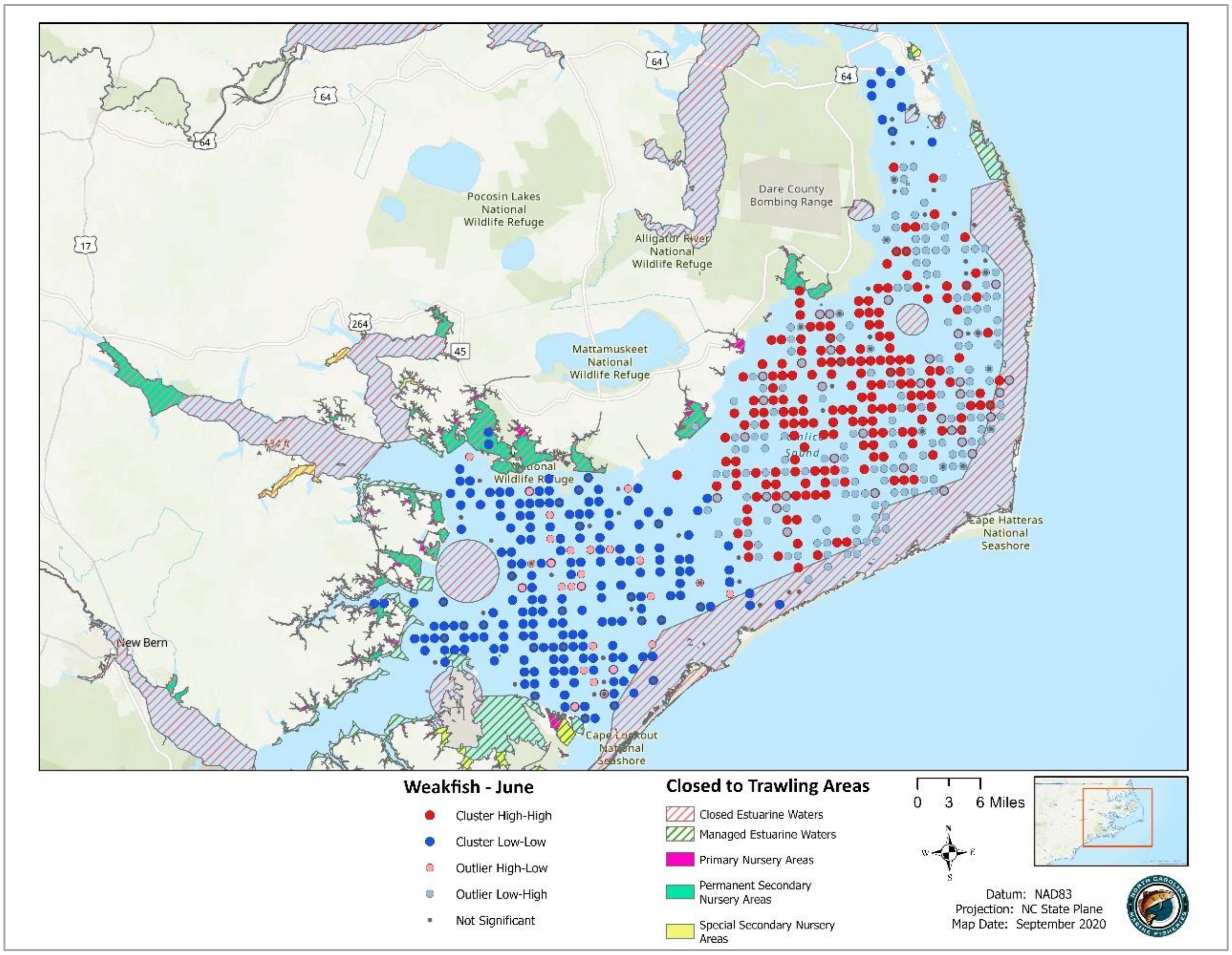
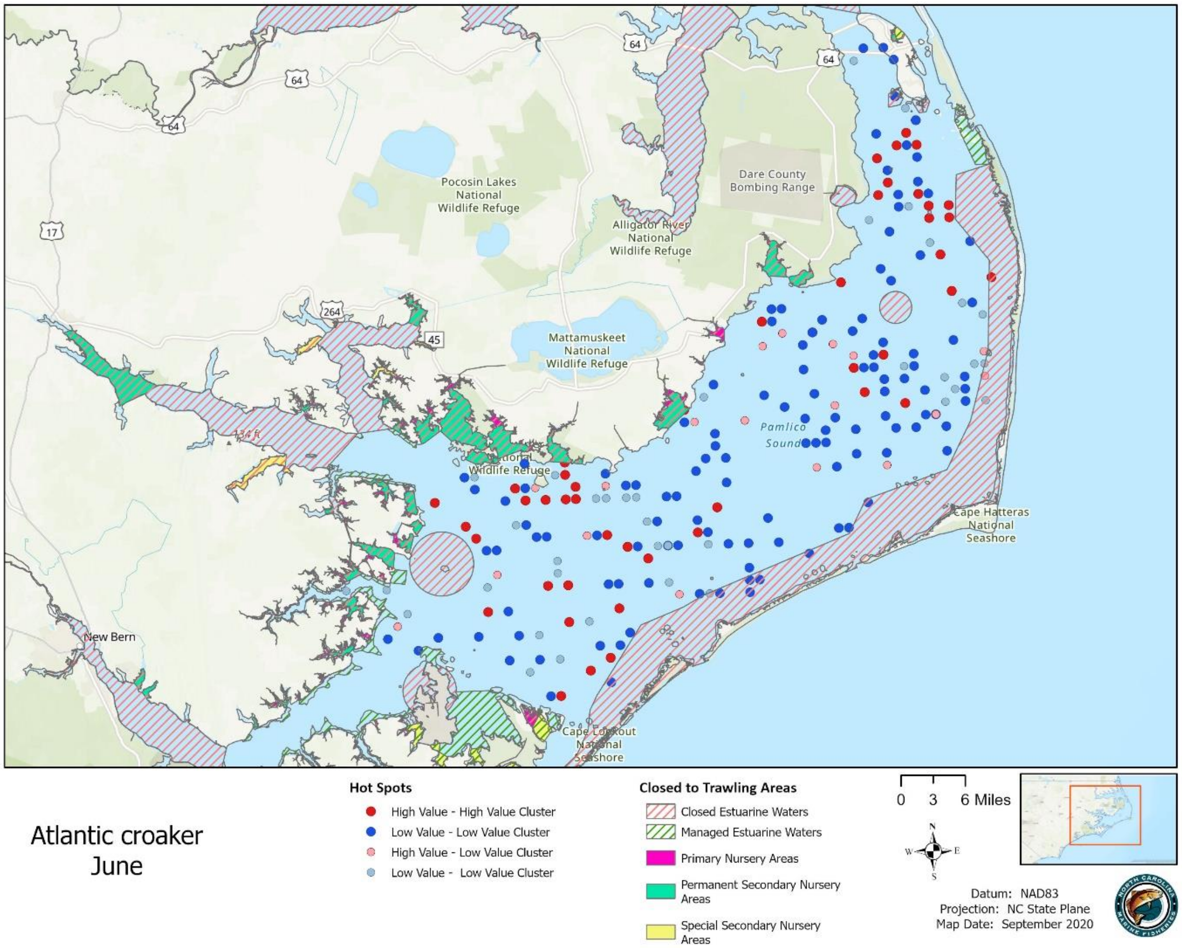
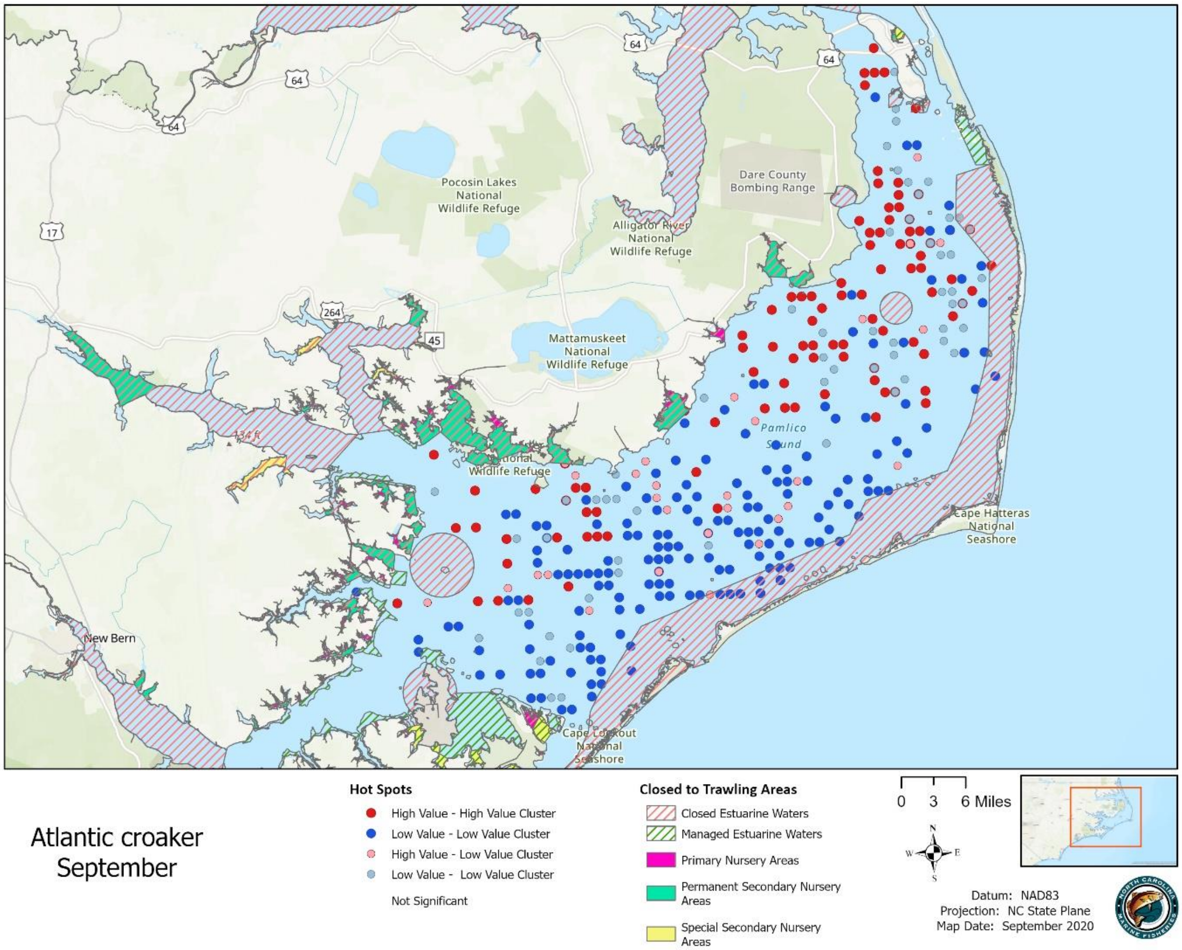


Figure 2.3.A.3. Results of OOA tool using weakfish data from June, between the years 1987-2019.

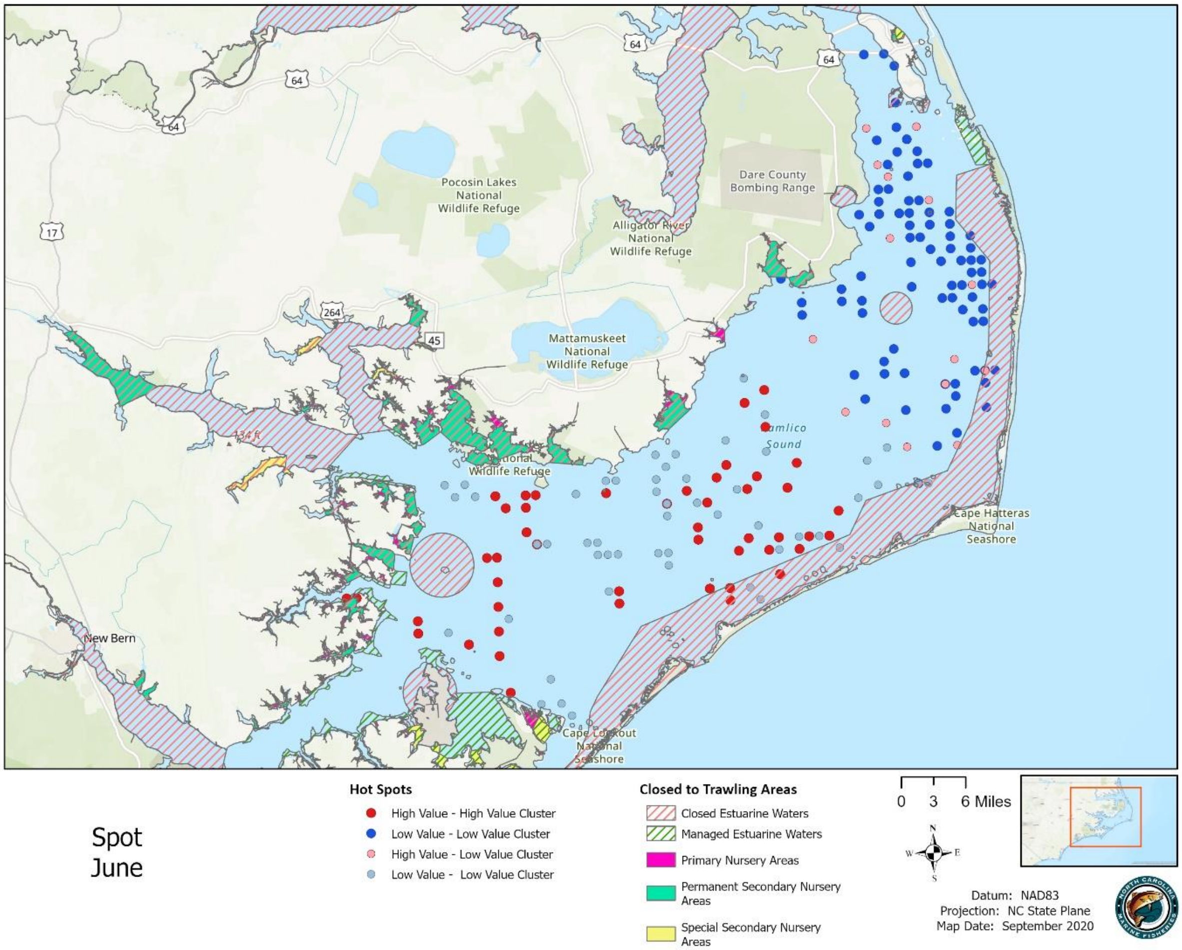
APPENDIX 2.3.B. MAPS OF HOT SPOTS OF ABUNDANCE IN PAMLICO SOUND



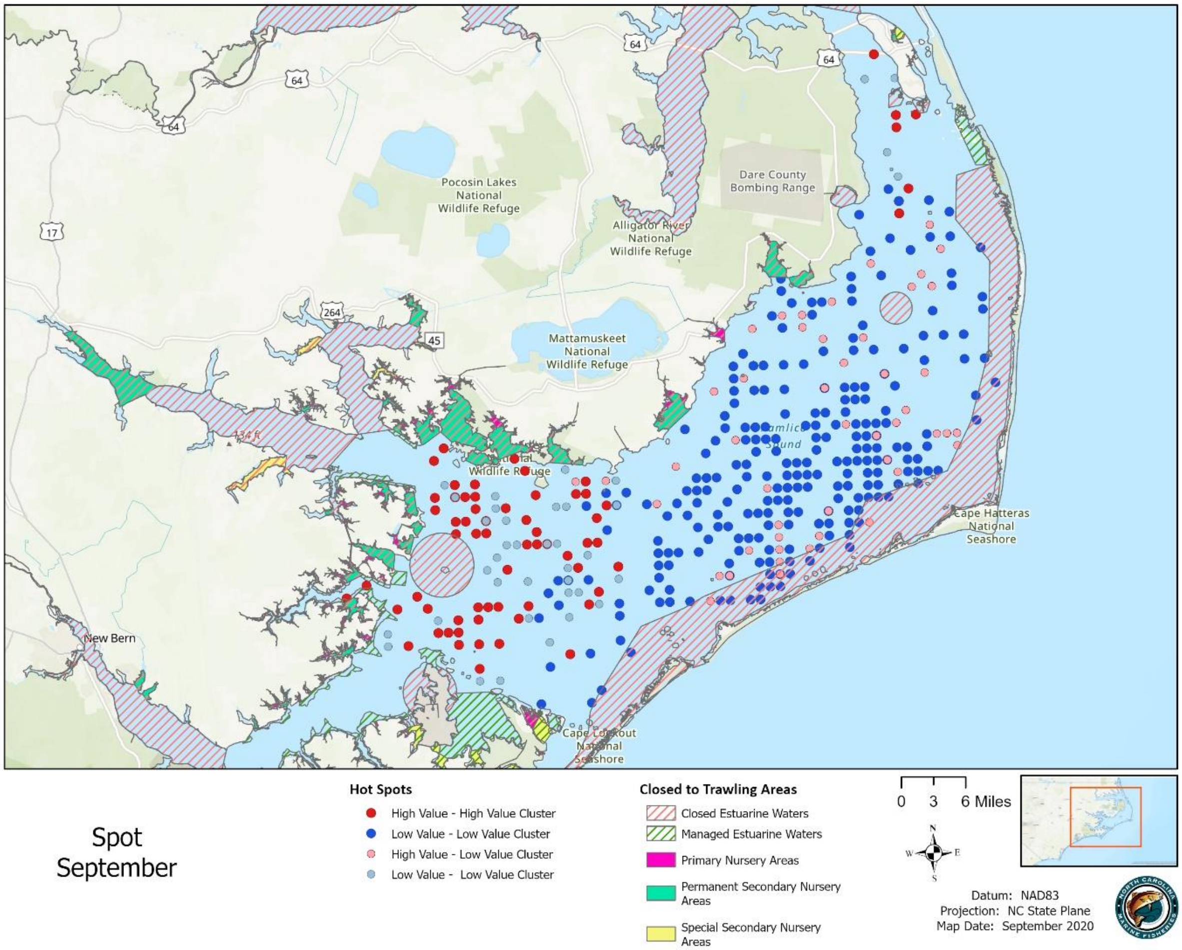
Map 2.3.B.1. Hot spots of abundance for Atlantic croaker in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



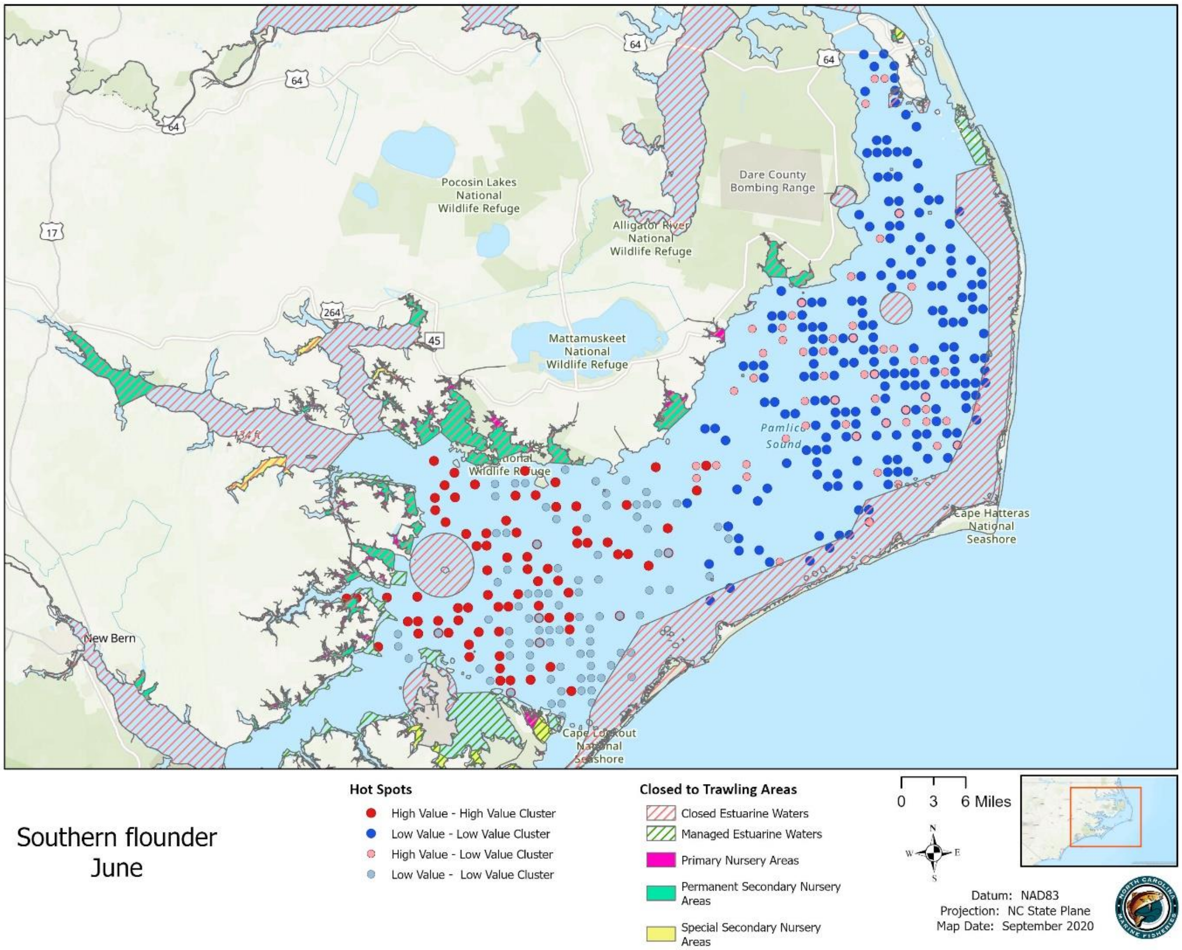
Map 2.3.B.2. Hot spots of abundance for Atlantic croaker in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



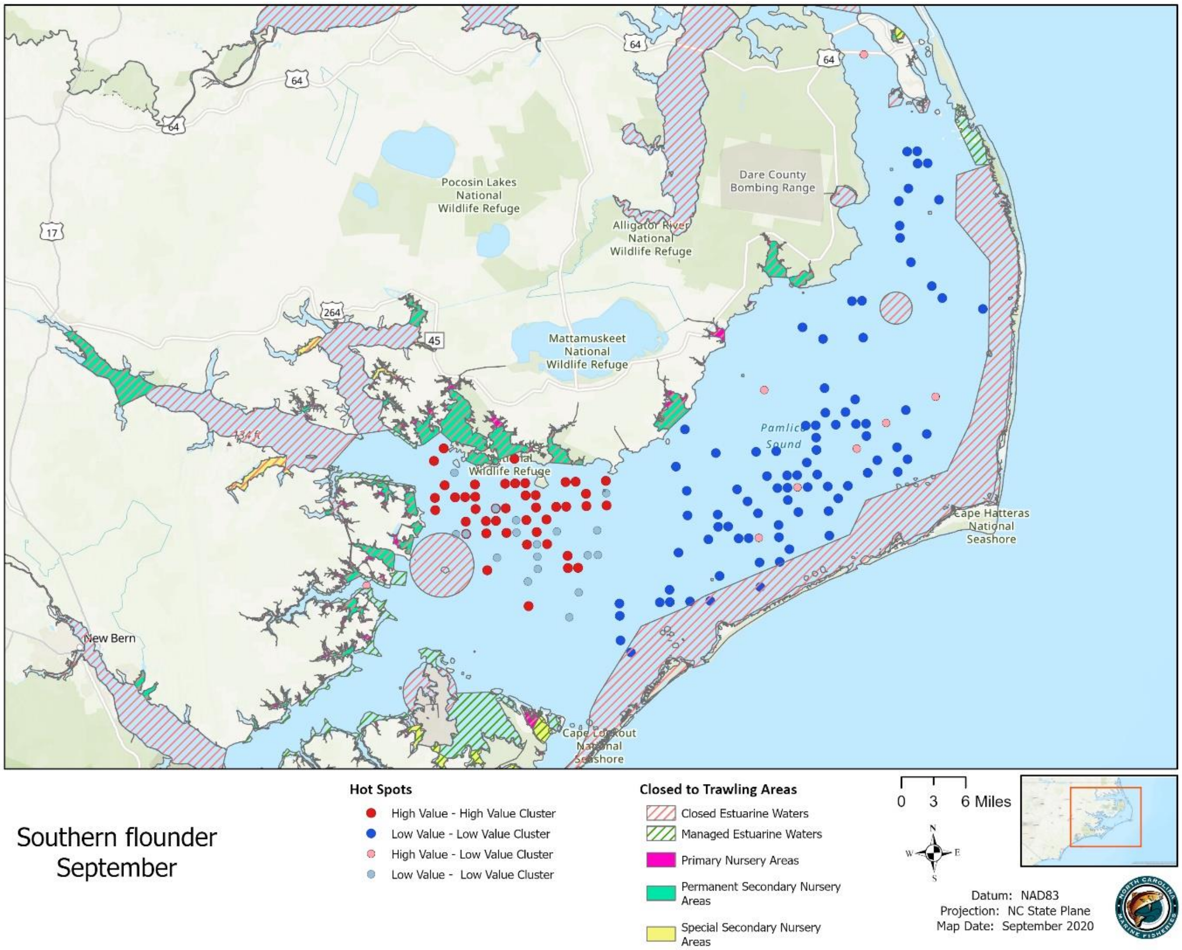
Map 2.3.B.3. Hot spots of abundance for spot in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



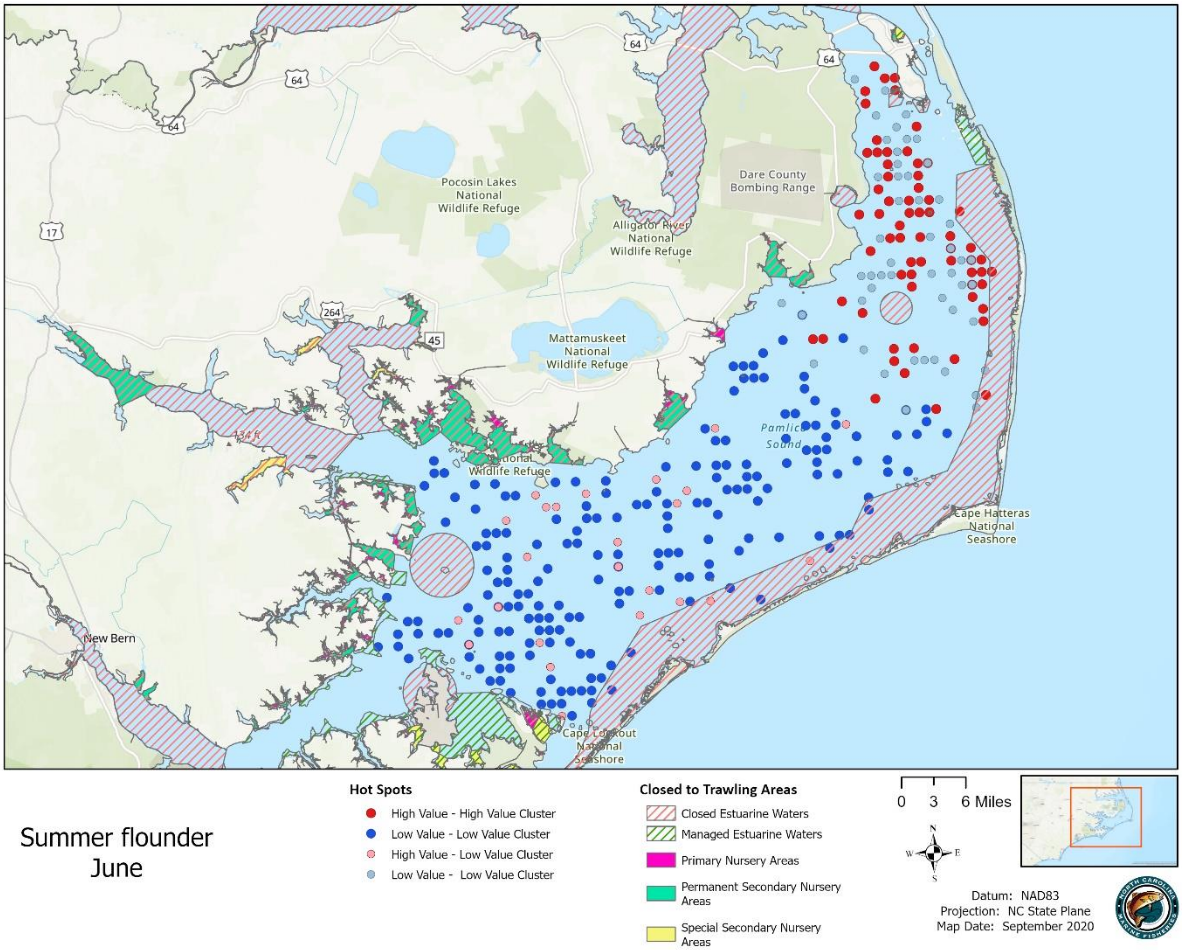
Map 2.3.B.4. Hot spots of abundance for spot in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



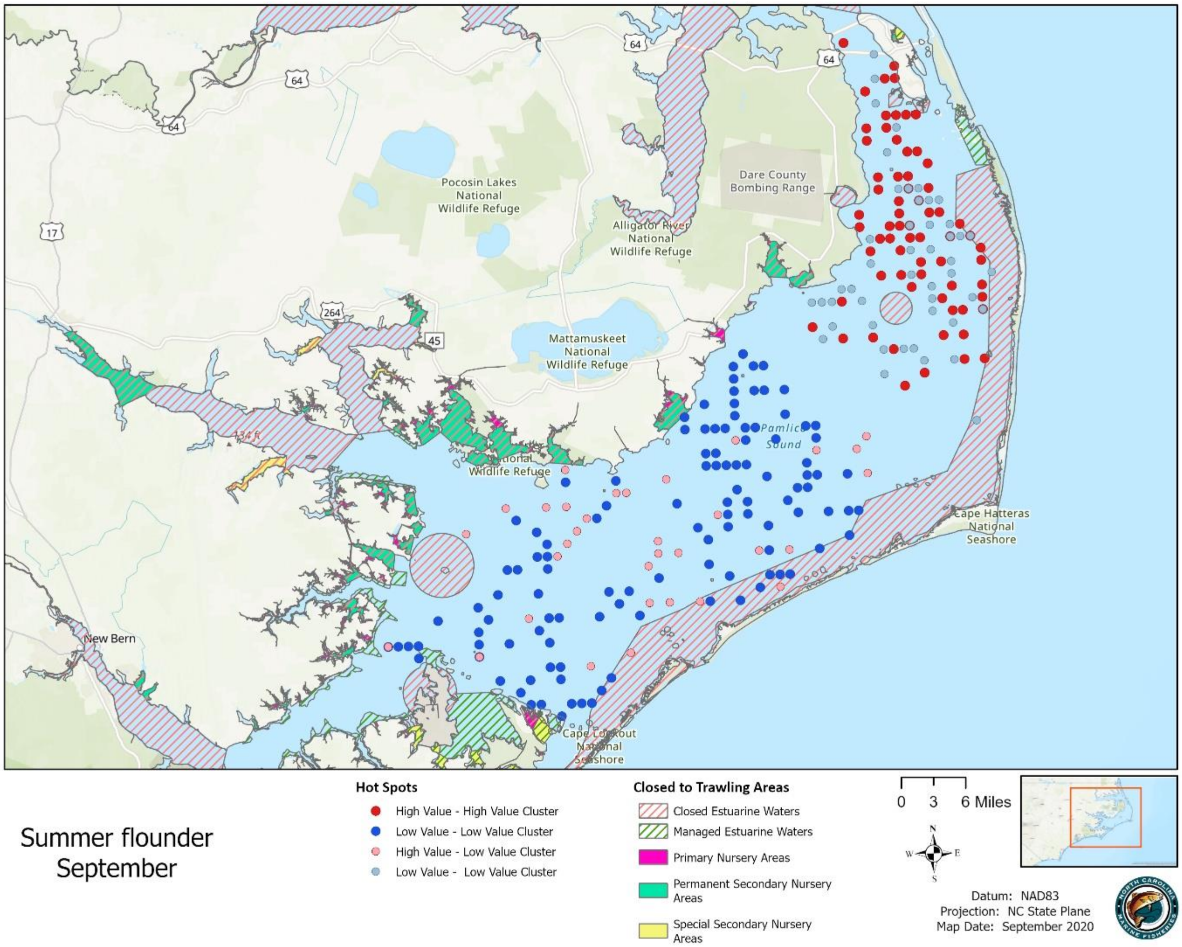
Map 2.3.B.5. Hot spots of abundance for southern flounder in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



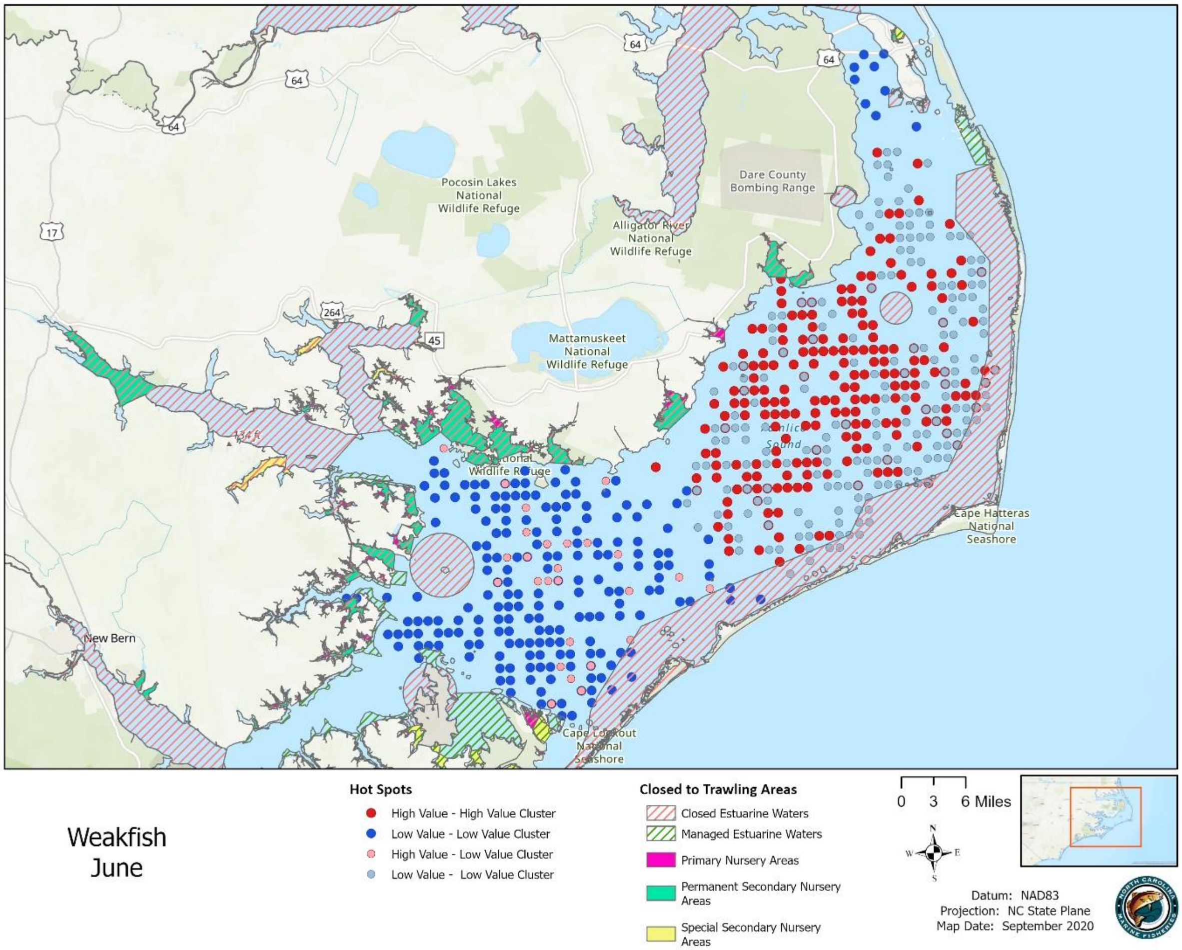
Map 2.3.B.6. Hot spots of abundance for southern flounder in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



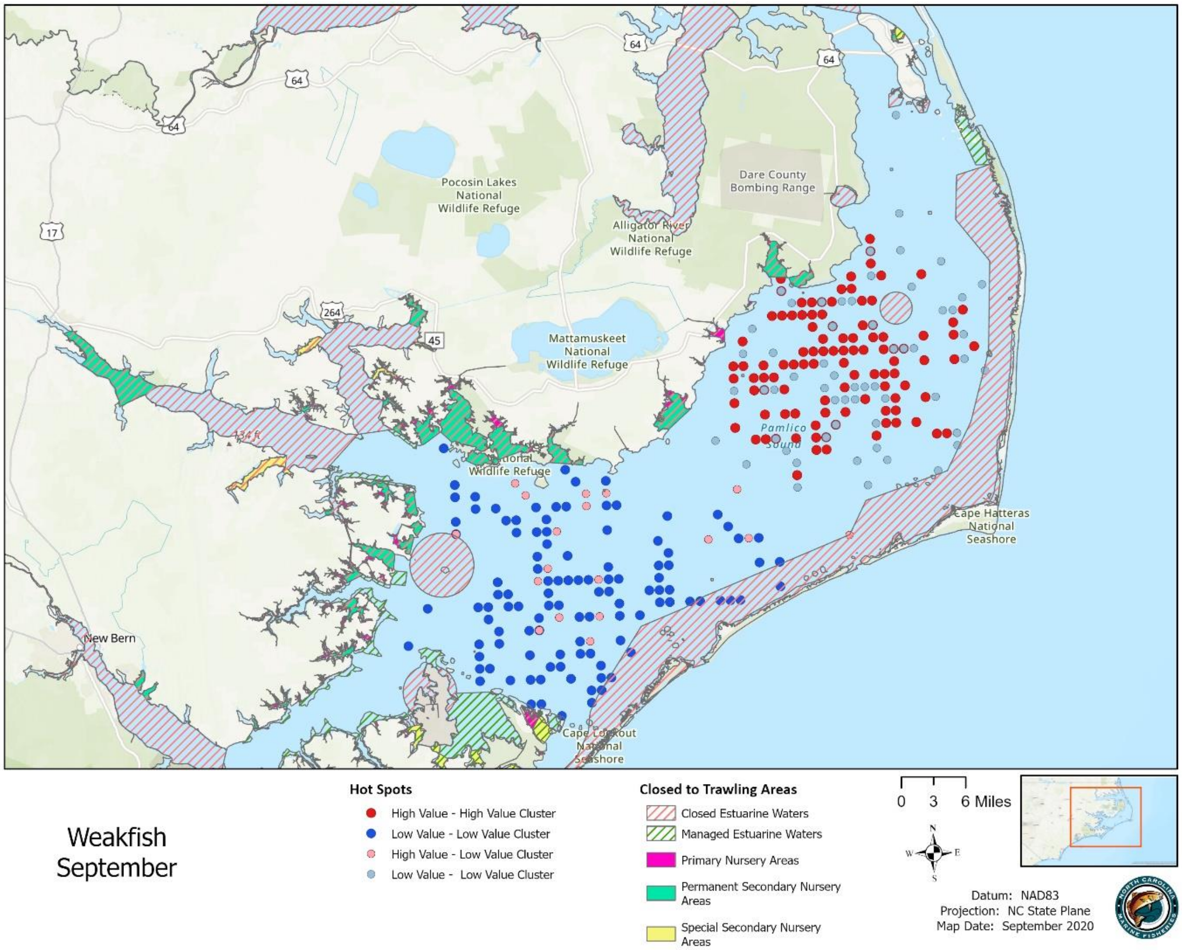
Map 2.3.B.7. Hot spots of abundance for summer flounder in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



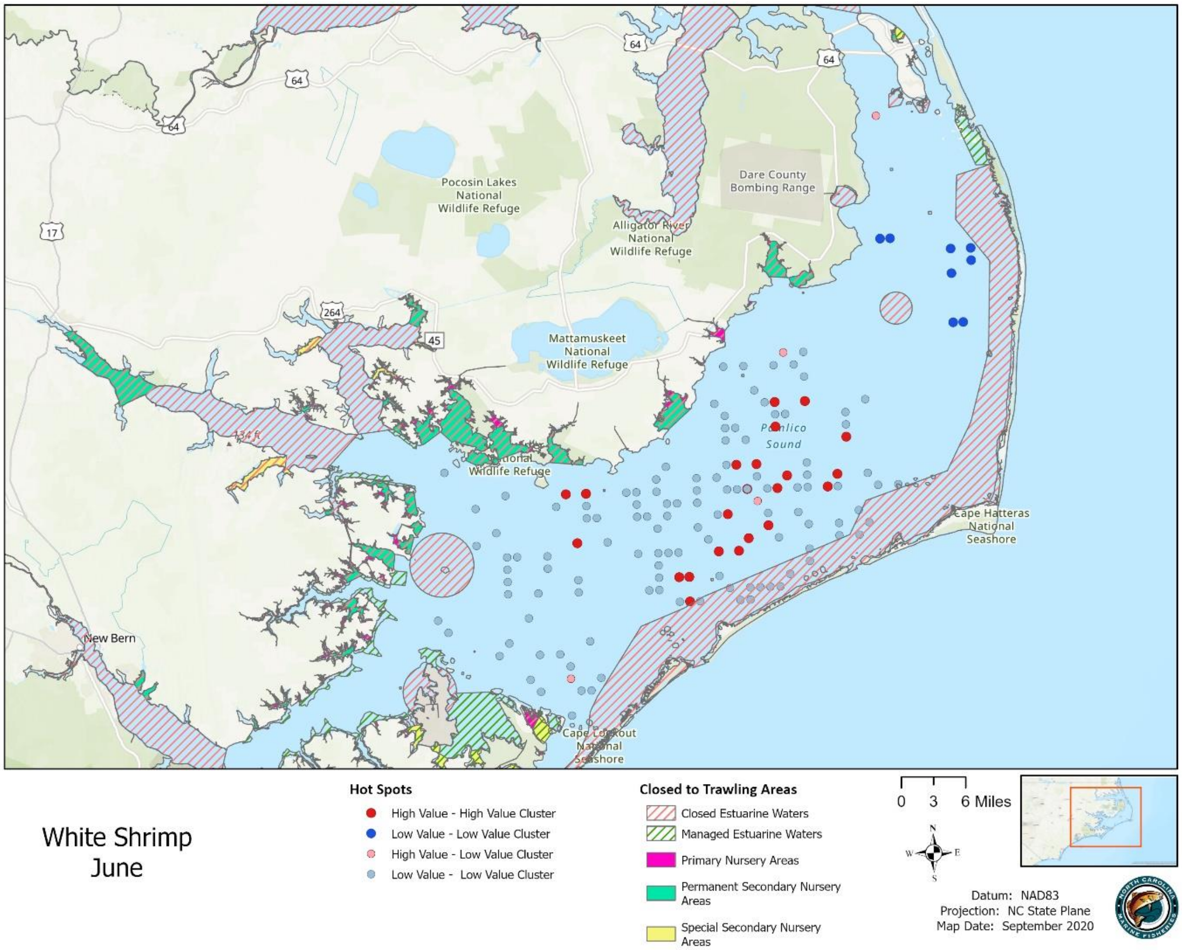
Map 2.3.B.8. Hot spots of abundance for summer flounder in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



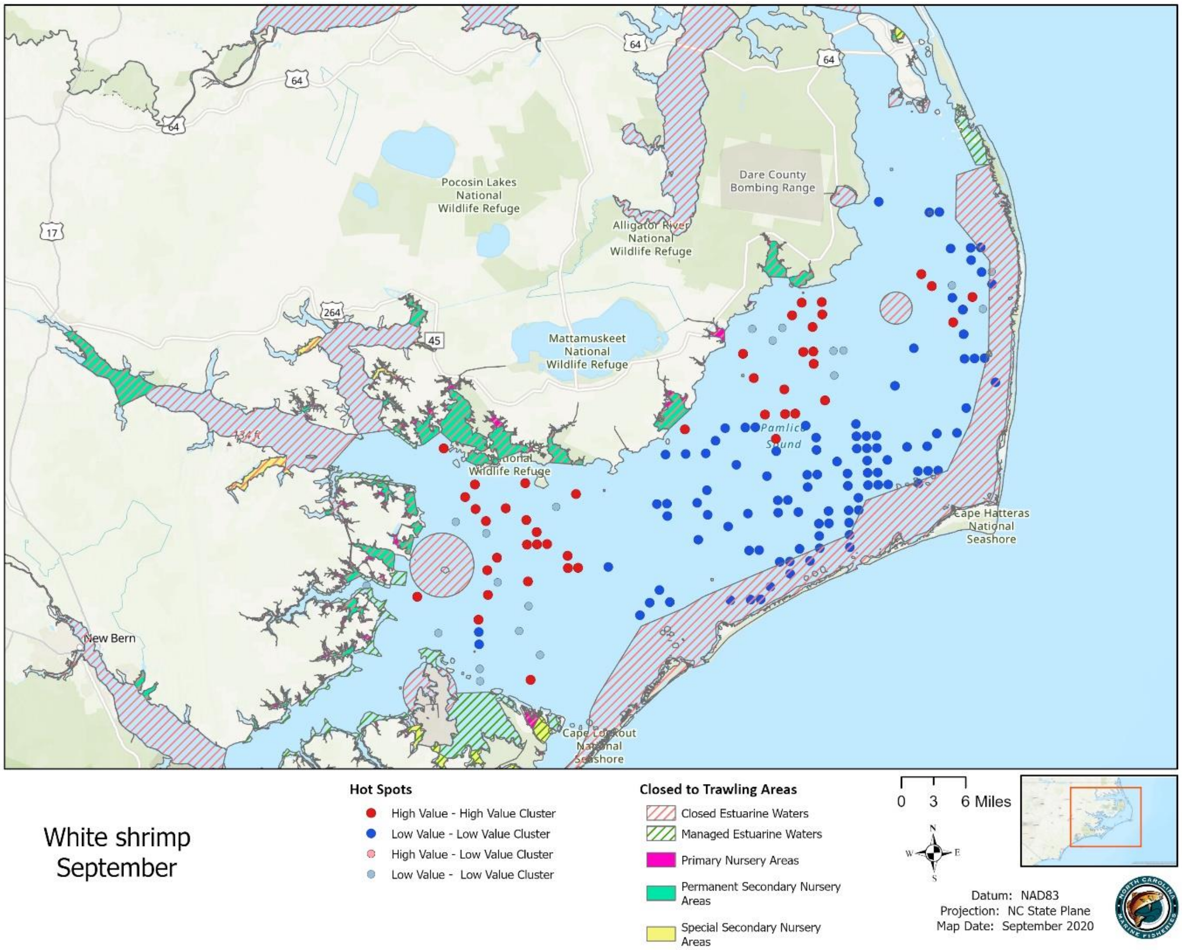
Map 2.3.B.9. Hot spots of abundance for weakfish in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



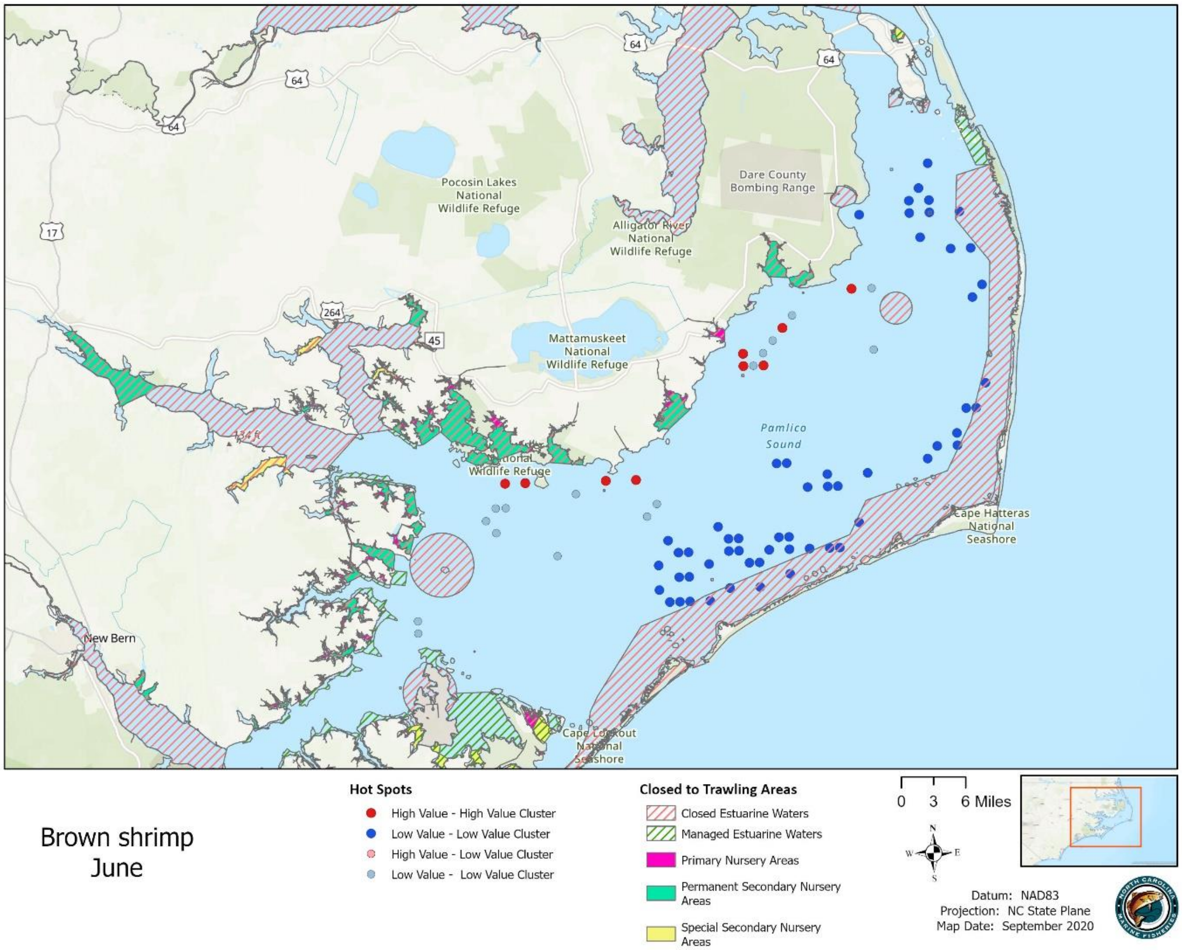
Map 2.3.B.10. Hot spots of abundance for weakfish in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



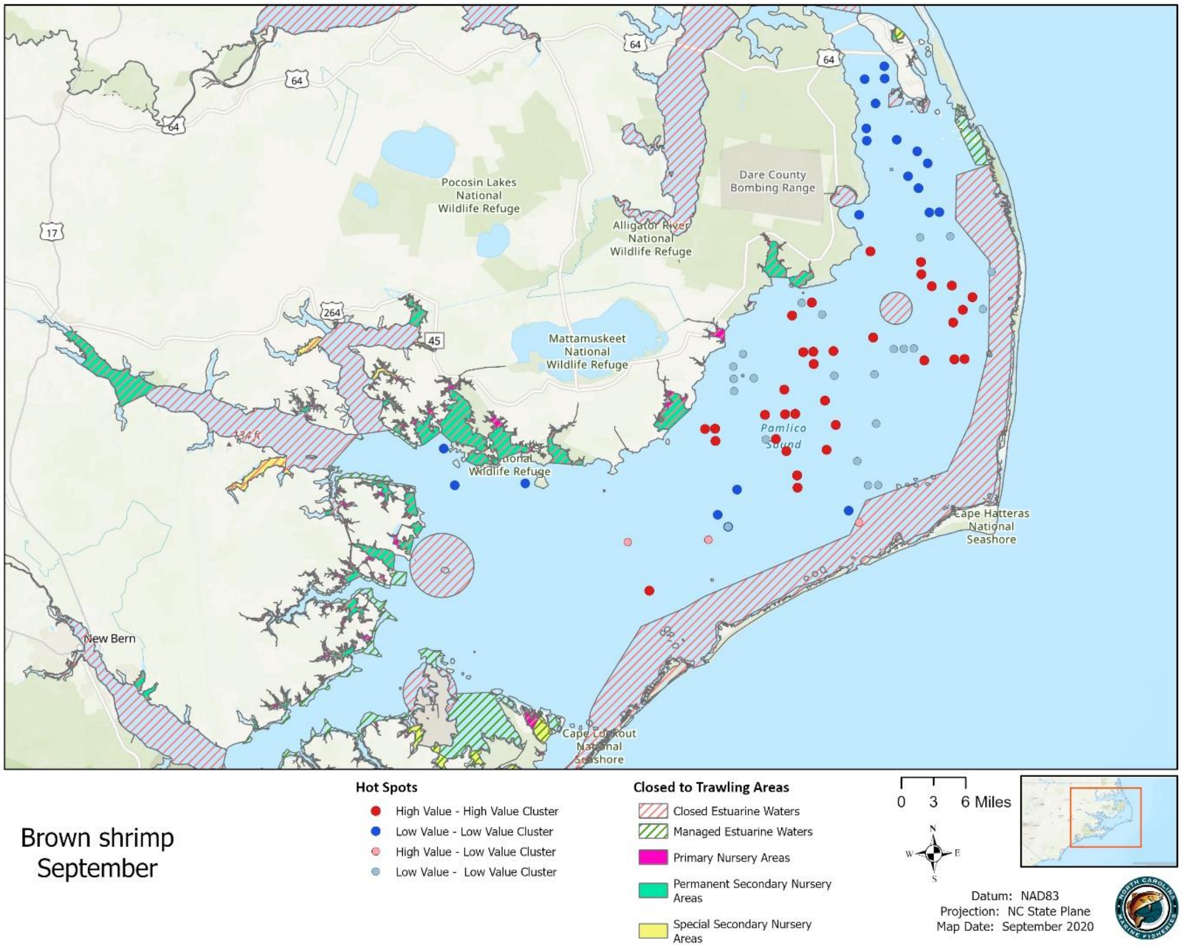
Map 2.3.B.11. Hot spots of abundance for white shrimp in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



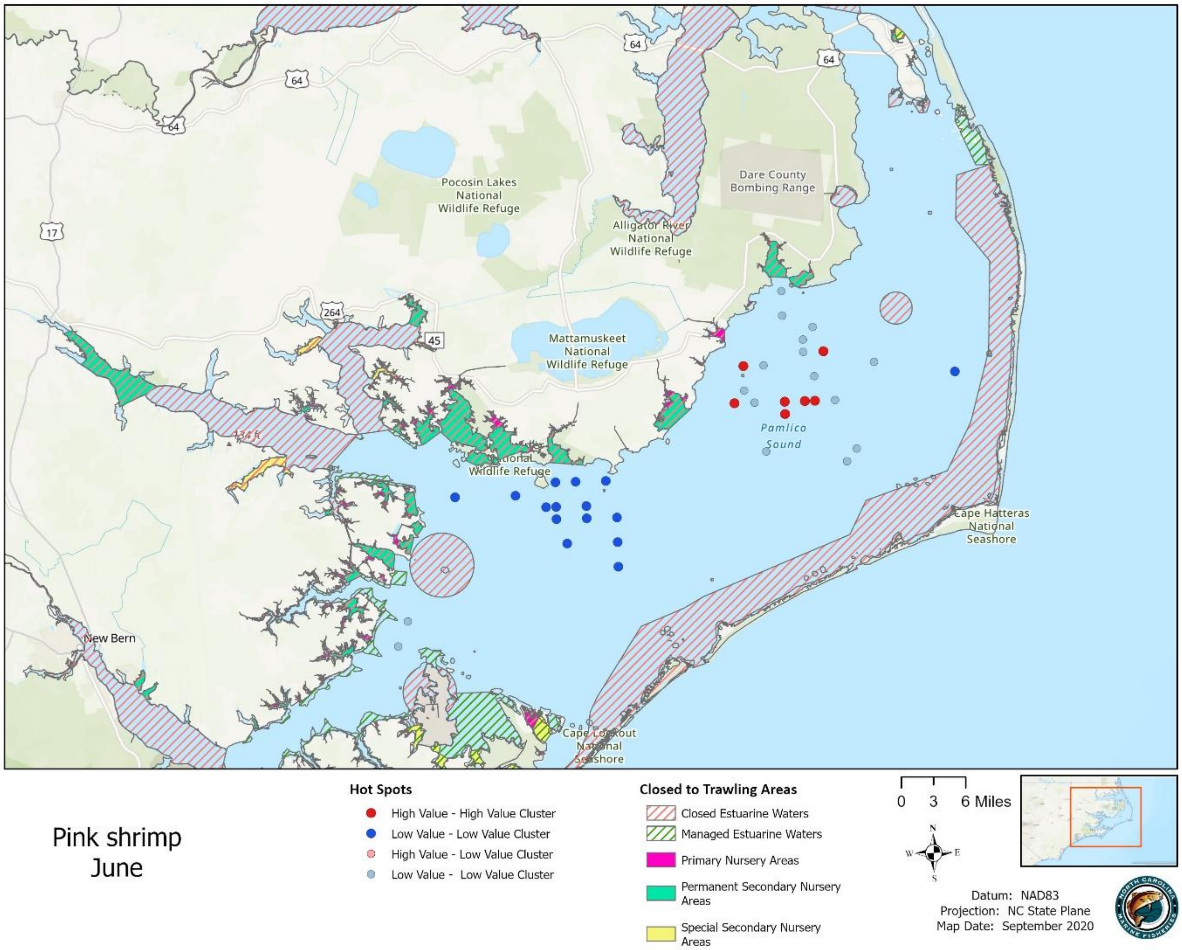
Map 2.3.B.12. Hot spots of abundance for white shrimp in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



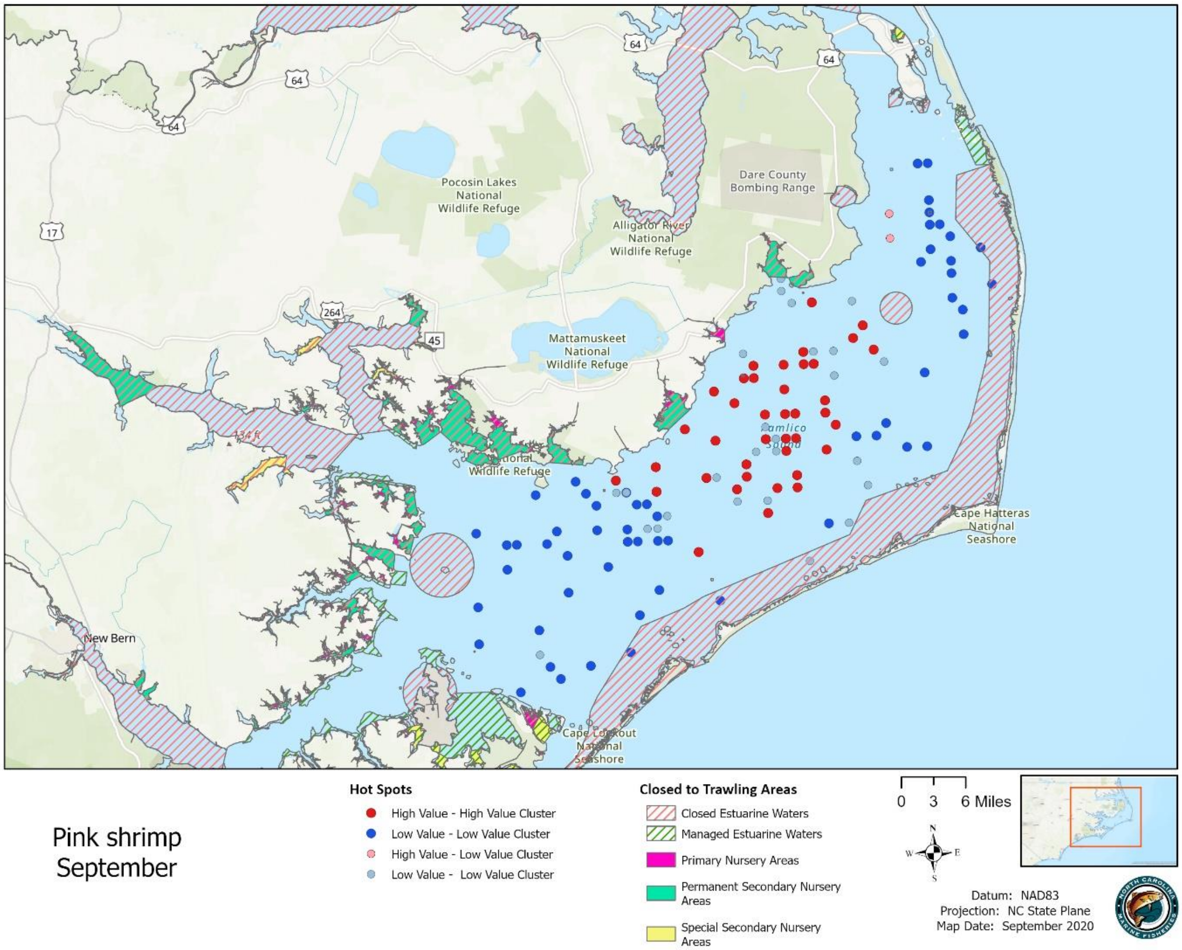
Map 2.3.B.13. Hot spots of abundance for brown shrimp in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



Map 2.3.B.14. Hot spots of abundance for brown shrimp in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.



Map 2.3.B.15. Hot spots of abundance for pink shrimp in the Pamlico Sound during June using aggregate data from Program 195, 1987-2019.



Map 2.3.B.16. Hot spots of abundance for pink shrimp in the Pamlico Sound during September using aggregate data from Program 195, 1987-2019.

APPENDIX 2.4. MANAGING EFFORT AND GEAR IN THE NORTH CAROLINA SHRIMP FISHERY TO REDUCE BYCATCH

I. ISSUE

Examine potential management measures to reduce bycatch in the North Carolina shrimp fishery through effort reductions and gear management.

II. ORIGINATION

This issue originated from concerns brought forth by the public, conservation groups, and the North Carolina Marine Fisheries Commission.

III. BACKGROUND

General Background on Bycatch

Bycatch is defined by the Atlantic States Marine Fisheries Commission (ASMFC) as “the portion of a catch taken incidentally to the targeted catch because of non-selectivity of the fishing gear to either species or size differences” (ASMFC 1994). In the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), bycatch is defined as “fish which are harvested in a fishery, but which are not sold or kept for personal use.” Fish in the MSFCMA is defined as finfish, mollusks, crustaceans, and all other forms of marine animal and plant life other than marine mammals and birds. Bycatch can generally be divided into two components: incidental catch and discarded catch. Incidental catch refers to retained catch of non-target species. Discarded catch is that portion of the catch returned to the sea because of economic, legal, or personal considerations. Differences in market prices for a given size-class of a species or limited storage space can also lead to “high grading”, where less valuable species and size classes are discarded to make space for more valuable fish (Bellido et al. 2011). The biological significance of bycatch can be judged from a number of different perspectives, including those of the populations (e.g., of a particular species), of the fishery or fisheries that target or otherwise encounter the species, and of the general biological community or ecosystem (Murawski 1995).

Through the years, interest in bycatch has shifted from its potential commercial use to concerns about impacts on finfish and other populations, biodiversity, and ecosystem trophic structure (Murray et al. 1992; Hall et al. 2000; Davies et al. 2009). Despite increased public awareness, greater management scrutiny, and significant research efforts, many basic questions remain unanswered. The biggest unanswered question in most fisheries is simply: *How much bycatch is there?* Given this situation, it is not surprising little is known about the impacts of bycatch on specific fisheries, fish populations, and marine communities. Although more information is needed to fully assess the effect of bycatch on fish populations and the ecosystem, continued concern and public policy dictates that bycatch be either eliminated or reduced to insignificant levels (Crowder and Murawski 1998). A prime example of this point can be found in the 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) which contained National Standard (#9) requiring bycatch minimization (USDOC 1996). National Standard 9 states: “Conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch." This has been maintained in each subsequent reauthorization of the MSFCMA [16 U.S.C. 1801 - 1891(d)]. Additionally, in 1991 the North Carolina Marine Fisheries Commission (NCMFC) adopted a policy directing the division to establish the goal of reducing bycatch losses to the absolute minimum and to consciously incorporate this goal into all management considerations (Murray et al. 1992).

It is apparent to scientists, natural resource managers, fishermen, and much of the public that bycatch is an important issue and must be addressed. However, characterizing the nature and extent of bycatch has proven difficult. These difficulties are generally attributed to inadequate monitoring of many pertinent fishery characteristics including actual bycatch levels, effort of the directed fishery, distribution of bycatch species, and the mortality rate of discarded species. The problem is exacerbated by the patchy distribution of effort and juvenile finfish in both time and space. The amount of bycatch generally varies from tow to tow (and depends on many factors), with many tows having some bycatch and fewer tows with high bycatch (Diamond 2003). Additionally, available effort data are often insufficient. Although research indicates tow duration is often a significant factor when estimating bycatch losses (e.g., mortality), the division and most other agencies typically record effort data by trip, without any accompanying information on tow duration or the number of tows made during a trip; although a few fisheries use logbooks to record effort metrics like tow time (Broadhurst et al. 2006; A. Bianchi, NCDMF, personal communication). Mortality of bycatch captured in shrimp trawls varies considerably, not only by species, but also in response to factors such as tow time and time out of water (Johnson 2003) as well as water temperature, fishing location, time of year, and gear configuration.

Several methods have been used to estimate shrimp trawl bycatch. One popular method of estimating bycatch is the ratio method. This method uses some information about the ratio of bycatch to the target catch caught by a gear or fishery and uses the reported landings of the target species multiplied by the ratio to estimate the total amount of bycatch (Diamond 2003). Typically, bycatch to catch ratios have been used to support or deny claims about how "clean" a fishery or gear is operated. As an example, if a particular gear or fishery has a bycatch to catch ratio of 1:5 it may be perceived to be a cleaner fishery than one with a 5:1 or even a 1:1 ratio. However, if the actual amount of bycatch is relatively equal in all these cases, then the variability in the ratio is caused by either differing target species or variations in the population of the target species. If the primary concern is the impact to the bycatch species, all the examples above have the same impact regardless of the bycatch to catch ratio. Therefore, the bycatch to catch ratio is not as informative as much as the actual catch rate (or total catch) of the bycatch species. A comparison among several ratio methods and a catch-per-unit-effort (CPUE) method found that the four ratio methods tested were more biased than the CPUE method. Additionally, the four ratio methods were more influenced by the mean or variance of the catch, observer coverage, and correlation between the bycatch and target catch (Diamond 2003). However, in most cases the data needed to calculate reliable CPUE estimates for bycatch species is lacking.

The lack of reliable discard estimates has not stopped researchers from investigating stock assessment impacts, but it has prevented increases in precision. Most stock assessments address the impact of bycatch through sensitivity analyses by comparing the basic stock assessment results over a range of bycatch estimates and assumptions [see 2010 Atlantic croaker stock assessment for an example of this approach (ASMFC 2010)]. If none of the results seem plausible, the stock assessment may proceed without bycatch estimates included but with the caveat that results may be biased or contain additional uncertainties due to unknown levels of missing catch. However, the omission of discard data may result in underestimating fishing mortality and lead to a biased stock assessment (Bellido et al. 2011).

Incidental Landings from Shrimp Trawls

The incidental landings of non-target species by shrimp trawls have declined significantly since 1994 (NCDMF Trip Ticket Program; Figure 2.4.1). On average, 125,402 pounds of incidental finfish catch were landed and sold annually from shrimp trawls from 2010 to 2019; representing 83.3% of all incidental landings sold during this period. Species where the effects of incidental landings and bycatch in shrimp trawls on their sustainability has been raised as a concern include spot (*Leiostomus xanthurus*), flounder (Paralichthid spp.), Atlantic croaker (*Micropogonias undulatus*), sheepshead (*Archosargus probatocephalus*), and weakfish (*Cynoscion regalis*). These species on average accounted 44% of the incidental landings annually from shrimp trawls from 1994 through 2009 (Figure 2.4.2). However, this has decreased substantially to only 17% from 2010 through 2019. Additionally, the magnitude of incidental landings has decreased significantly over time (Figure 2.4.3). The largest decreases in incidental landings have been seen for weakfish (98%), Atlantic croaker (97%), flounder (93%), and spot (90%) when comparing the average landings for the 1994 through 1999 period to the 2015 through 2019 period. Incidental landings of kingfishes have declined (34%), but since their decrease has been less dramatic than other species their overall proportion of incidental bycatch landings has increased over time (Figures 2.4.2 and 2.4.3). Sheepshead landings have generally remained consistently low, averaging less than 4,000 pounds annually. Incidental landings of crabs [blue crab (*Callinectes sapidus*); Florida stone crab (*Menippe mercenaria*), horseshoe crab (*Limulus Polyphemus*)] have declined since the 1990s (Figure 2.4.1), averaging 17,750 poundsannually and making up 12% of the total landings for 2010 through 2019. Incidental landings of mollusks (conch/whelks, squid, octopus spp.) have generally declined (Figure 2.4.1), averaging 7,426 pounds annually and 5% of the total landings for 2010 through 2019. Additional species-specific landings information is included in the species sections below.

Discarded Bycatch in Shrimp Trawls

Over 200 species of finfish and crustaceans have been identified in the North Carolina shrimp trawl fishery in recent years (Brown 2009, 2010, 2015, 2016, 2017, 2018; Brown et al. 2017, 2018, 2019). In both estuarine and ocean waters, Atlantic croaker and spot were the most abundant bycatch species. While southern flounder (*Paralichthys lethostigma*), summer flounder (*P. dentatus*), and weakfish typically make up the largest portion of regulatory discards, they only account for a small portion of the total catch by weight. Additional species-specific information for discarded bycatch is included in the species sections below.

Shrimp Trawl Bycatch Impacts on Stock Assessments

Discards are a significant source of mortality that must be accounted for to estimate total removals from a population (Alverson and Hughes 1996; Nance 1998; Bellido et al 2011). Most quantitative stock assessment techniques involve statistical analysis of catch data that require an accurate record of the entire catch to reliably estimate stock parameters such as recruitment, abundance, and selectivity. Therefore, it is not only important to know the magnitude of discarded bycatch, but the age composition as well (Alverson et al. 1994; Murawski 1995). Omitting discard data can underestimate recruitment and mortality at age and further lead to biased stock assessments (Punt et al. 2006) and stock predictions (Alverson et al. 1994). Recently, discard estimates from the shrimp trawl fishery were incorporated into stock assessments for Atlantic croaker (ASMFC 2017a), spot (ASMFC 2017b), and southern flounder (Flowers et al. 2019), and was attempted for weakfish (ASMFC 2016).

While stock assessment models can help fisheries managers evaluate the relative impact of natural and fishing mortality on a stock, it is difficult to quantify how finfish stocks will improve or change in response to management measures put in place to reduce bycatch due to the many unpredictable human and natural factors that affect fish stock abundance. Habitat quality and fish stock abundance is not only influenced by directed fishing but is also influenced by factors that cannot be controlled through fishery management strategies, such as environmental fluctuations (e.g., pH, temperature, dissolved oxygen, storms), habitat loss due to land development, water quality, and natural morality rates specific to each species. Furthermore, it is not possible to estimate net changes in fishing effort, temporal and geographic shifts in fishing patterns, and changes in gear and targeted species that could affect fishing mortality and bycatch both positively and negatively. Additional species-specific information regarding stock assessment impacts is included in the species sections below.

Bycatch Management in North Carolina

Concerns about bycatch in North Carolina began in the 1950s after serious declines in the catch of commercial fish were observed in North Carolina waters with attention focused on the shrimp fishery in Pamlico Sound (NCDMF 2015). In the 1960s and early 1970s, directed finfish trawling in the ocean for bait and pet food led to the NCMFC establishing rules to prohibit directed scrap fishing (taking the young of edible fish before they are of sufficient size to be valuable as individual food fish). In 1977, the NCMFC began designating nursery areas to protect both the physical habitat, as well as juvenile finfish and crustaceans. The Albemarle Sound was closed to trawling in 1987 due to conflicts with crab pot and gill net fishermen as well as concerns about bycatch and habitat. North Carolina was the first state to mandate the use of bycatch reduction devices (BRDs) in all shrimp trawls in 1992. The use of BRDs installed in penaeid shrimp trawls can reduce total bycatch by 30 to 70% (McHugh et al. 2017).

The National Marine Fisheries Service first mandated the use of turtle excluder devices (TEDs) in shrimp trawls for inshore (unless following tow time restrictions) and offshore waters in 1987 [Sea Turtle Conservation; Shrimp Trawling Requirements, 50 C.F.R §217, 222, and 227 (1987)]. The use of TEDs has not only been shown to reduce the number of sea turtle stranding's and takes in the shrimp trawl fishery but has also been shown to reduce finfish bycatch (Brewer et al. 2006; Broome et al. 2011; Price and Gearhart 2011). In 1993, NCDMF wrote a comprehensive report on estuarine trawling that addressed bycatch, overfishing, and habitat and water quality concerns. Based on the findings of this report, rules were established in 1994 that prohibited trawling in seagrass beds in eastern Pamlico Sound, eliminated weekend trawling, and established special secondary nursery areas (SSNA) which could be opened by proclamation from August 16 through May 14.

In 2006, the first Shrimp FMP implemented several management measures to address bycatch concerns which included effort controls and gear modifications (NCDMF 2006). Gear modifications and effort controls included: 1) prohibiting the use of otter trawls upstream of the Highway 172 Bridge in the New River; therefore, limiting trawling to skimmer trawls which have been shown to minimize and increase survivability of bycatch (Coale et al. 1994; Hein and Meier 1995) and 2) a maximum combined 90 ft headrope length limit was established for all internal waters except Pamlico Sound and the mouths of the Pamlico and Neuse rivers. This measure was meant to reduce conflict between small and large vessels but may have also helped to reduce bycatch of juvenile finfish and crustaceans as well as protect habitat.

In February 2015, the NCMFC adopted Amendment 1 to the Shrimp FMP which contained management measures to reduce bycatch in the commercial and recreational shrimp trawl fishery (NCDMF 2015). It increased the number of certified BRDs available for use, required two BRDs in shrimp otter trawls and skimmer trawls, and established a maximum combined headrope length of 220 feet in all internal coastal waters where no maximum combined headrope limit previously existed. An industry workgroup was also formed to test gear modifications to reduce finfish bycatch in the shrimp trawl fishery by an additional 40%. Four of the gear configurations tested reduced bycatch an additional 40 to 57% (Brown et al. 2019). In July 2019, the use of these gear configurations was mandated in all shrimp otter trawls operating in Pamlico Sound and portions of Pamlico, Bay, and Neuse rivers through the May 2018 Revision to Amendment 1 (NCDMF 2018). These gear modifications reduce finfish bycatch in shrimp otter trawls by approximately 60% when compared to a net without a TED and any BRDs.

NCDMF Shrimp Trawl Bycatch Characterization Studies

Six commercial shrimp trawl bycatch characterization studies were conducted from July 2007 to December 2017 (Table 2.4.1; Brown 2009, 2010, 2015, 2016, 2017, 2018). The studies observed catches from commercial shrimp trawls (skimmer and otter) in a variety of estuarine waters inside and outside of Pamlico Sound, as well as the nearshore ocean waters (0-3 miles) of North Carolina. Observations were made on a total of 756 fishing days, consisting of 2,068 tows. Additional species-specific information for the characterization studies is included in the species sections below.

Bycatch Species Information

The species included in this section are either commonly caught as bycatch in shrimp trawls and their stock status is either unknown or they are overfished and/or overfishing is occurring (e.g., Atlantic croaker, southern flounder, spot, and weakfish), there are concerns over increased bycatch due to recent shifts in effort by the shrimp trawl fishery (e.g., sheepshead), or they are protected under the Endangered Species Act or Marine Mammal Protection Act (e.g., sea turtle species, Atlantic sturgeon, bottlenose dolphin).

ATLANTIC CROAKER

Harvest from Shrimp Trawls

Harvest of Atlantic croaker in the ocean otter trawl fishery from 1994 through 2019 averaged 41,781 pounds and ranged from three to 545,123 pounds. Harvest in the ocean skimmer trawl fishery occurred in only two years of the time series and averaged less than 10 pounds. Harvest in the estuarine (excluding Pamlico Sound) otter trawl fishery averaged less than 200 pounds and ranged from 0 to 1,057 pounds. Harvest in the estuarine (excluding Pamlico Sound) skimmer trawl fishery averaged 9 pounds and ranged from 0 to 58 pounds. Harvest in the Pamlico Sound otter trawl fishery averaged 1,948 pounds and ranged from 19 to 10,678 pounds. Harvest in the Pamlico Sound skimmer trawl fishery occurred in only three years during the time series and averaged less than 10 pounds.

Characterization Studies

In the six characterization studies conducted from July 2007 to December 2017, Atlantic croaker was the most abundant finfish bycatch, representing between 5% (Study 4) and 42% (Study 3) of the catch by weight. The observed at net mortality ranged from 0% (Study 4, fall season) to 57% (Study 4, spring season). Across all studies, most Atlantic croaker ranged from 100 to 180 mm (Table 2.4.1).

Stock Assessment/Status

In 2017, a benchmark stock assessment was completed (ASMFC 2017a). This assessment used a stock synthesis model to address a major source of uncertainty from previous assessments – the magnitude of Atlantic croaker bycatch in South Atlantic shrimp trawl fishery (North Carolina through Florida). However, due to conflicting trends in abundance and harvest, as well as other uncertainties, this assessment was not recommended for management use (ASMFC 2017a). A traffic light approach is used to evaluate Atlantic croaker fishery trends and develop management actions when harvest and abundance thresholds are exceeded (ASMFC 2020a).

The 2017 assessment did show most annual removals of Atlantic croaker were discards from the South Atlantic shrimp trawl fishery, followed by commercial landings and recreational harvest. Annual discards from the South Atlantic shrimp trawl fishery ranged from 180 million pounds to 1.1 billion pounds with a long term mean of 396 million pounds. Shrimp trawl bycatch accounted for 81 to 99% of annual Atlantic croaker removals and averaged 91.6% of all removals. The peer reviewers recognized that discard/bycatch estimates are unusually uncertain due to data insufficiencies, but agreed the method used to develop estimates of Atlantic croaker bycatch from the South Atlantic shrimp trawl fishery was current, supported, and similar (or identical) to methods used in Southeast Data, Assessment, and Review (SEDAR) assessments of South Atlantic king mackerel (*Scomberomus cavalla*), Gulf of Mexico red snapper (*Lutjanus campechanus*), gray triggerfish (*Balistes capriscus*), and domestic sharks.

SPOT

Harvest from Shrimp Trawls

Harvest of spot in the ocean otter trawl fishery from 1994 through 2019 averaged 17,218 pounds and ranged from 1,807 to 52,662 pounds. Harvest in the ocean skimmer trawl fishery occurred in only two years of the time series and averaged 45 pounds. Harvest in the estuarine (excluding Pamlico Sound) otter trawl fishery averaged 1,793 pounds and ranged from 105 to 7,511 pounds. Harvest in the estuarine (excluding Pamlico Sound) skimmer trawl fishery averaged 135 pounds and ranged from 0 to 822 pounds. Harvest in the Pamlico Sound otter trawl fishery averaged 12,695 pounds and ranged from 293 to 52,037 pounds. Harvest in the Pamlico Sound skimmer trawl fishery averaged 34 lb.

Characterization Studies

In the six characterization studies conducted from July 2007 to December 2017, spot represented between 0.7% (Study 6, otter trawls in the ocean) and 23% (Study 3) of the catch by weight. The observed at net mortality ranged from 66% (Study 3) to 82% (Study 4). Across all studies, most spot ranged from 100 to 180 mm (Table 2.4.1).

Stock Assessment/Status

In 2017, the first coastwide benchmark stock assessment was completed for spot (ASMFC 2017b). The assessment used a catch survey model to estimate population parameters (e.g., stock status, natural mortality, discard rates, and mortality) and biological reference points. However, due to conflicting trends in abundance and harvest, as well as other uncertainties, this assessment was not recommended to be used for management advice (ASMFC 2017b). A traffic light approach is used to evaluate spot fishery trends and develop management actions when harvest and abundance thresholds are exceeded (ASMFC 2020b).

Most fishery removals of spot were discards in the South Atlantic shrimp trawl fisheries, followed by commercial landings and recreational harvest. The panelists recognized discard/bycatch estimates are unusually uncertain due to data insufficiencies, but agreed the method used to develop estimates of spot bycatch from the southern shrimp trawl fishery was current, supported, and similar (or identical) to methods used in SEDAR assessments of South Atlantic king mackerel, Gulf of Mexico red snapper, gray triggerfish, and domestic sharks.

WEAKFISH

Harvest from Shrimp Trawls

Harvest of weakfish in the ocean otter trawl fishery from 1994 through 2019 averaged 2,008 pounds and ranged from 29 to 26,644 pounds. Harvest in the ocean skimmer trawl fishery occurred in only one year of the time series and averaged less than 10 lbs. Harvest in the estuarine (excluding Pamlico Sound) otter trawl fishery averaged 276 pounds and ranged from zero to 1,956 pounds. Harvest in the estuarine (excluding Pamlico Sound) skimmer trawl fishery averaged two pounds and ranged from zero to six pounds. Harvest in the Pamlico Sound otter trawl fishery averaged 5,847 pounds and ranged from 36 to 43,600 pounds. Harvest in the Pamlico Sound skimmer trawl fishery averaged six lb.

Characterization Studies

In the six characterization studies conducted from July 2007 to December 2017, weakfish represented between 0.1% (Study 5, in skimmer trawls in estuarine waters) and 6% (Study 2) of the catch by weight. The observed at net mortality ranged from 87% (Study 3) to 100% (Study 5). Across all studies, most weakfish were less than 305 mm (12 inches; Table 2.4.1).

Stock Assessment/Status

The 2016 Weakfish Stock Assessment attempted to include estimates of shrimp trawl discards from the South Atlantic (ASMFC 2016). However, the final estimates of weakfish bycatch were very small relative to total commercial removals. The catch from shrimp trawls consisted of mainly age-0 fish which were not included in the model. There was also high uncertainty in the data set due to low sample size, the lack of mandatory observer coverage prior to 2008, and uncertainty in extrapolating catch estimates further into the past. For these reasons, estimates of shrimp trawl bycatch were not included in the assessment. They also explored the NCDMF shrimp trawl observer dataset, but due to the limited temporal and spatial coverage, estimates of weakfish bycatch were not developed. Both the 2016 stock assessment and an updated stock assessment conducted in 2019 found the weakfish stock was depleted (ASMFC 2019).

SOUTHERN FLOUNDER

Harvest from Shrimp Trawls

The NCDMF Trip Ticket Program does not distinguish between summer and southern flounder species and therefore designates southern flounder as being harvested from estuarine waters (hence no ocean landings are produced). Harvest in the estuarine (excluding Pamlico Sound) otter trawl fishery averaged 2,419 pounds and ranged from 83 to 17,024 pounds. Harvest in the estuarine (excluding Pamlico Sound) skimmer trawl fishery averaged 114 pounds and ranged from 0 to 365 pounds. Harvest in the Pamlico Sound otter trawl fishery averaged 18,393 pounds and ranged from 449 to 88,967 pounds. Harvest in the Pamlico Sound skimmer trawl fishery averaged 12 lbs.

Characterization Studies

In the six characterization studies conducted from July 2007 to December 2017, southern flounder represented between 0.01% (Study 6) and 1.6% (Study 3, in 2013 season in estuarine otter trawls) of the catch by weight. The observed at net mortality ranged from 0% (Study 3, in 2012) to 88% (Study 5, in 2015). Across all studies, most southern flounder ranged from 80 to 300 mm (Table 2.4.1).

Stock Assessment/Status

The assessment model estimated a value of 0.35 for $F_{35\%}$ (fishing mortality target) and a value of 0.53 for $F_{25\%}$ (fishing mortality threshold; Flowers et al. 2019). The estimate of *F* in 2017 is 0.91, which is above the threshold ($F_{25\%}$ = 0.53) and suggests overfishing is currently occurring. The estimate of spawning stock biomass target ($SSB_{35\%}$) was 5,452 mt and the estimate of $SSB_{25\%}$ (threshold) was 3,900 mt. The model estimate of SSB in 2017 was 1,031 mt, which is below the threshold and suggests the stock is currently overfished (Flowers et al. 2019).

The shrimp trawl fishery was modeled as a bycatch-only fleet and the input landings included only dead discards. No live discards were assumed for the shrimp trawl fishery. Estimates of southern flounder bycatch in the shrimp trawl fishery have shown a general decline over time and were not a major source of fishing mortality (Flowers et al. 2019).

SHEEPSHEAD

Harvest from Shrimp Trawls

Harvest of sheepshead in the ocean otter trawl fishery from 1994 through 2019 averaged 3,048 pounds and ranged from 201 to 13,894 pounds. Harvest in the ocean skimmer trawl fishery occurred in only one year of the time series and averaged less than 10 pounds. Harvest in the estuarine (excluding Pamlico Sound) otter trawl fishery averaged 166 pounds and ranged from 10 to 1,098 pounds. Harvest in the estuarine (excluding Pamlico Sound) skimmer trawl fishery averaged 18 pounds and ranged from 0 to 117 pounds. Harvest in the Pamlico Sound otter trawl fishery averaged 916 pounds and ranged from 89 to 2,561 pounds. Harvest in the Pamlico Sound skimmer trawl fishery averaged 6 lb.

Characterization Studies

In the six characterization studies conducted from July 2007 to December 2017, sheepshead represented between 0% (Study 2) and 0.2% (Study 1) of the catch by weight. Across all studies, sheepshead ranged from 182 to 388 mm (Table 2.4.1).

Stock Assessment/Status

No formal stock assessment has been completed for sheepshead in North Carolina; however, one is being prepared by researchers at North Carolina State University with results expected sometime in 2021.

PROTECTED SPECIES

Protected species (sometimes referred to as "protected resources") is a broad term that encompasses a range of organisms protected by federal or state statutes because their populations are at risk or are vulnerable to risk of extinction. Federal statutes include the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and the Migratory Bird Treaty Act (MBTA). Of federally protected species found in North Carolina, only sea turtles, sturgeon species, and the common bottlenose dolphin (*Tursiops truncatus*) are known or suspected to be incidentally taken in the shrimp fishery. Due to their protected status, harvest of these species is prohibited.

Sea Turtles

Common sea turtles in North Carolina include the Kemp's ridley sea turtle (*Lepidochelys kempii*), hawksbill sea turtle (*Eretmochelys imbricate*), leatherback sea turtle (*Dermochelys coriacea*), green sea turtle (*Chelonia mydas*), and the loggerhead sea turtle (*Caretta caretta*). After a decline in sea turtle populations and their listing under the endangered species act in 1977, it was determined that the primary cause of sea turtle mortality was the incidental capture as bycatch in the southeast U.S. shrimp fishery (Henwood and Stuntz 1987; National Research Council 1990). This was addressed through regulatory decisions and the development and use of a TED. TEDs in trawls are estimated to have a 97% exclusion rate with minimal shrimp loss (Watson 1981; Murray 2020). Recent studies have shown that sea turtles can exhibit symptoms of decompression sickness, commonly known as "the bends" from forced submergence in bottom trawls which can be greatly reduced through the use of a TED (García-Párraga et al., 2014; Fahlman et al., 2017). In August 2021, the National Oceanic and Atmospheric Administration (NOAA) Fisheries is expected to require the use of TEDs in all skimmer trawls over 40 ft.

Bottlenose Dolphin

While bottlenose dolphins are commonly seen feeding behind shrimp trawlers in North Carolina (Fleming 2004; Johnson 2006; Brown 2009), very few takes have been observed in the shrimp trawl fishery. However, in the Gulf of Mexico, otter trawls have been identified as a significant source of mortality and serious injury for several species of dolphin (Soldevilla et al. 2015).

Atlantic Sturgeon

The bycatch of Atlantic sturgeon (*Acipenser oxyrinchus*) from a variety of fisheries (gill nets, pound nets, trawls, etc.) is thought to be the primary source of mortality and biggest threat to the species recovery (ASMFC 2017c). Results from the 2017 Atlantic Sturgeon Stock Assessment indicate the total and dead bycatch of Atlantic sturgeon from otter trawls has declined since 2002 and the stock is showing signs of recovery (ASMFC 2017c). It should be noted that bycatch estimates from the South Atlantic shrimp trawl fishery was not evaluated for inclusion in the stock assessment for several reasons (i.e., under-reporting of takes, inappropriate survey methods, time series limitations). Continued bycatch monitoring and development of new BRD and TED configurations should further aid in their recovery. In an evaluation of TED designs used in the Mid-Atlantic Atlantic croaker flynet fishery, Atlantic sturgeon were observed escaping through TED openings (Gearhart 2010) and may further be excluded from shrimp trawls.

Characterization Studies

In the six characterization studies conducted from July 2007 to December 2017, there were 16 total protected species interactions observed. The interactions comprised 13 sea turtles, two Atlantic sturgeon, one bird, and zero marine mammals. Details about specific interactions for each study are found in Table 2.4.1.

Effort in the Shrimp Fishery

OTTER TRAWL

Effort in the otter trawl sector of the North Carolina shrimp fishery based on the number of participants and vessels has been relatively steady since 2005 (Figure 2.4.4) and has averaged 381 participants and 416 vessels annually in the shrimp otter trawl fishery for 2010 through 2019. Similarly, the number of trips and total number of trip days have remained relatively steady since 2005 (Figure 2.4.5) and has averaged 5,762 trips and 10,499 trip days in the shrimp otter trawl fishery for 2010 through 2019. However, from 2015 through 2019, the number of trips and trip days have been increasing, although they are still well below the highs seen in the early 2000s. The pounds of shrimp harvested by otter trawls fluctuates annually, sometimes by millions of pounds from one year to the next; the value of the fishery also follows a similar pattern (Figure 2.4.6). However, landings and value from 2016 through 2019 are among the highest in the time series, driven largely by increased landings of white shrimp in the Atlantic Ocean north of Cape Hatteras. From 2010 through 2019, landings have averaged 7.7 million pounds with an ex-vessel value of $17.0 million.

Otter trawl effort by area (Pamlico Sound, other inshore waters, and ocean) shows a similar pattern as the overall trend (Figure 2.4.7). Participants, vessels, trips, and trip days for all three areas declined in the early 2000s and then stabilized from 2006 to 2019 in most cases. The average length of commercial otter trawl trips (Figure 2.4.8) has remained relatively stable throughout the time series for all areas. The average trip length in Pamlico Sound ranged from 2.5 to 3 days, while in other inshore waters trip length averaged about 1 day per trip. Trip lengths in the ocean averaged about 1.5 days for most of the time series but in recent years increased to an average of about two days per trip. When looking at trip days keep in mind this does not equate to fishing days. Trip days includes travel time, lay days, bad weather days, etc. in addition to fishing days.

SKIMMER TRAWL

Effort in the skimmer trawl sector of the North Carolina shrimp fishery based on the number of participants and vessels has been relatively steady since 2005 (Figure 2.4.9) and has averaged 64 participants and 69 vessels annually in the shrimp skimmer trawl fishery for 2010 through 2019. However, from 2018 through 2019, both participants and vessels have declined sharply. Similarly, the number of trips and total number of trip days have remained relatively steady since 2005 (Figure 2.4.10) and has averaged 806 trips and 851 trip days in the shrimp skimmer trawl fishery for 2010 through 2019. However, from 2016 through 2019, the number of trips and trip days have decreased sharply and are well below the highs seen in the early 2000s. The amount of shrimp harvested by skimmer trawls fluctuates annually, sometimes by hundreds of thousands of pounds from one year to the next, the value of the fishery also follows a similar pattern (Figure 2.4.11). Landings and value from 2018 through 2019 are among the lowest in the time series. From 2010 through 2019, landings have averaged 345,779 pounds with an ex-vessel value of $534,808.

Further examination of skimmer trawl effort trends by area (Pamlico Sound and other inshore waters). shows a similar pattern as the overall trend (Figure 2.4.12). Participants, vessels, trips, and trip days declined in the early 2000s and then stabilized around 2006 until recent years when there was a sharp decline in all effort metrics. In Pamlico Sound, effort was stable (though at a much lower level than other inshore areas) from the mid-2000s until the past few years when there was a sharp increase in effort (presumably due to increased white shrimp abundance). The average length of commercial skimmer trawl trips (Figure 2.4.13) has remained relatively stable throughout the time series in other inshore waters at roughly 1 day per trip and in Pamlico Sound the average trip length ranged from 1.5 to two days. Ocean data (as well as Pamlico Sound data in some years) was not included because there were no trips or trip data were considered confidential (< 3 trips). When looking at trip days keep in mind this does not equate to fishing days. Trip days includes travel time, lay days, bad weather days, etc. in addition to fishing days.

CHANNEL NETS, CAST NETS, AND OTHER GEARS

Effort in the shrimp fishery from non-trawl gears (i.e., channel nets, cast nets, etc.) is relatively low compared to trawl gears. The number of participants using non-trawl gears fluctuates annually and the number of participants using channel nets, cast nets, and other gears has averaged 62, 11, and 17 participants, respectively for 2010 through 2019 (Figure 2.4.14A). Similarly, the number of trips using non-trawl gears fluctuates annually and the number of trips using channel nets, cast nets, and other gears has averaged 903, 52, and 157 trips, respectively, for 2010 through 2019 (Figure 2.4.14B). Shrimp landings from non-trawl gears is relatively low compared to shrimp trawls. Landings from channel nets, cast nets, and other gears has averaged 166,157,818, and 10,959 pounds, respectively for 2010 through 2019 (Figure 2.4.14C). Similar to landings, the value of the harvest from non-trawl gears is relatively low compared to the value of shrimp trawl harvest. The ex-vessel value of landings from channel nets, cast nets, and other gears has averaged $266,279, $4,025, and $23,034, respectively for 2010 through 2019 (Figure 2.4.14D).

Current Gear Modifications and Effort Reduction Management Measures

HEADROPE LIMIT

The size of gear allowed in North Carolina's shrimp fishery has been the subject of debate, particularly with respect to trawls. Prior to the 2006 Shrimp FMP, there were size limits on channel nets and on recreational shrimp trawls (26 ft headrope length) used by Recreational Commercial Gear License (RCGL) holders, but no restriction on the size of trawls used in the commercial shrimp fishery. At the time, many fishermen felt there should be a maximum limit placed on the size of trawls particularly in some smaller water bodies. They cited it was unfair to allow larger vessels into these areas especially on opening days when many boats would crowd into an area. Small vessel operators thought the larger vessels took most of the shrimp, rendering areas unproductive for several days, and then left to fish in more open waters unworkable by the smaller vessels. Currently, it is unlawful to use shrimp trawls (otter and skimmer) with a combined headrope length greater than 90 ft in internal coastal waters of North Carolina, except in the Pamlico Sound and mouths of the Pamlico and Neuse rivers where up to 220 ft of combined headrope may be used [NCMFC Rule 15A NCAC 03L .0103(c)(d)]. There is no limit on the amount of headrope that can be fished in the state ocean waters. The 90 ft headrope areas were primarily established due to conflicts between small and large trawlers, not to limit or reduce bycatch in those areas. The 220 ft headrope limit in Pamlico Sound was established to cap fleet capacity and not to limit or reduce bycatch.

MESH SIZE

For all net types, it is unlawful to use nets with an inner or outer mesh liner. Net material used as chaffing gear must have a mesh length of at least four inches, except smaller mesh may be used along the bottom half of the tailbag. Chaffing gear may not be tied in a way that forms an additional tailbag [NCMFC Rule 15A NCAC 03L. 0103L(b)].

Otter and Skimmer Trawls

The minimum mesh size for otter and skimmer trawls is one and one-half inches [NCMFC Rule 15A NCAC 03L. 0103L(a)(1)]. Except, in areas where up to 220 ft of headrope is allowed (Pamlico Sound and portions of the Pamlico and Neuse rivers), the minimum tailbag mesh size is one and three-quarter inches (Proclamation SH-3-2019).

Channel Nets, Float Nets, Butterfly Nets, Hand Seines, and Cast Nets

The minimum mesh size for channel nets, float nets, butterfly nets, and hand seines is one and one-quarter inches [NCMFC Rule 15A NCAC 03L. 0103L(a)(2)]. There is no minimum mesh size for cast nets [NCMFC Rule 15A NCAC 03L. 0103L(a)(3)].

<u>Other Shrimp Trawl Gear Modifications</u>

BYCATCH REDUCTION DEVICES

Bycatch reduction devices are required to be used in all trawls used to harvest shrimp. Proclamation SH-3-2019 describes the BRD requirements for otter trawls in Pamlico Sound and the mouths of the Pamlico and Neuse rivers. Allowable BRDs in these areas include: 1) two Federal Fisheyes placed inline or 2) the Virgil Potter BRD and one Florida Fish Excluder. Otter trawls in all other waters and skimmer trawls statewide are required to have two BRDs installed on each net. The primary BRD must be one of the following: 1) Florida Fish Excluder, 2) Federal Fisheye, 3) Gulf Fisheye, 4) Eight Inch PVC "Sea Eagle" Fish Excluder, 5) General Eight Inch and Ten Inch Large Mesh and Extended Mesh Funnel BRD, 6) Eight Inch and Ten Inch Inshore Large Mesh and Extended Funnel BRD, 7) Large Mesh Funnel Excluder, 8) Jones-Davis BRD, 9) Modified Jones-Davis BRD, 10) Cone Fish Deflector Composite Panel, or a 11) Square Mesh Composite Panel. The secondary BRD may include: 1) a second BRD listed above, 2) Reduced Bar Spacing TED (<3 inches), or 3) a T-90 or Square Mesh (T-45) tailbag. The BRD requirements in all areas do not apply to single test trawls (also called a try net) with a headrope of 12 feet or less provided: 1) the net is pulled immediately in front of another net or is not connected to another net in any way, 2) no more than one net is used at a time, and 3) the net is not towed as a primary net.

TURTLE EXCLUDER DEVICES

The use of a federally approved TED is required in all trawls in accordance with federal rules and are adopted by reference through NCMFC Rule 15A NCAC 03L 0103(h). Currently all otter trawl nets are required to have a federally approved TED if using mechanical retrieval methods. Beginning August 1, 2021, it is expected that skimmer trawl vessels 40 ft and greater must have a federally approved TED installed in each net. The new TED requirements for skimmer trawls state the bar spacing may not be greater than three inches (compared to otter trawls which are allowed bar spacings up to four inches). Skimmer trawl vessels less than 40 ft will not be required to use TEDs and instead are allowed to use minimum tow times in accordance with federal rules.

FISHING DAYS RESTRICTIONS

The present 9:00 p.m. Friday through 5:00 p.m. Sunday evening closure for Internal Coastal Waters [NCMFC Rule 15A NCAC 03J. 0104(b)(1)] evolved from a February 1984 petition from fishermen to close Core Sound from 8:00 a.m. Saturday to 6:00 a.m. Monday by proclamation so they had time to rest, make boat and gear repairs, etc. Although some fishermen and dealers complained that they needed shrimp for the Monday morning market and there was a fear of effort shifting to adjacent open areas, there was some support for a Sunday night closure. A proposal to close from Saturday morning through Monday morning by rule failed. Fishermen continued to request a weekend closure, and this was tried in July 1984 by proclamation. Core Sound, North, South, and Newport rivers, and Turnagain, Rataan, Cedar, Long, and West bays, and Adams Creek were closed on the weekend from July 15 through December 31, 1984 and this was continued from that time on in some fashion. In 1993 the weekend closure was adjusted to begin one hour after sunset on Fridays and end one hour before sunset on Sundays. A 1993 effort by the NCMFC to extend the closure through Monday morning failed. Actual times (9:00 p.m. and 5:00 p.m.) were implemented in 2004 to avoid confusion with varying times found on sunrise/sunset tables.

DAILY FISHING TIME RESTRICTIONS

In North Carolina it is unlawful to trawl for shrimp in the Atlantic Ocean off Brunswick County, 9:00 p.m. to 5:00 a.m. [NCMFC Rule15A NCAC 03J .0202 (8)]. This management measure was implemented in large part to reduce the bycatch of finfish in this gear. Ingraham (2003) examined this question by conducting a study of shrimp and finfish catch rates (day vs. night) in state waters from Topsail Inlet to Little River Inlet. Data from the study showed that finfish bycatch was higher at night than during the day. Of the nine commercially important finfish species caught, southern flounder, spot, Atlantic croaker, and southern kingfish (*Menticirrhus americanus*) catch rates were significantly higher at night. The catch of shrimp did not vary significantly between nighttime and daytime trawling, although catches were slightly higher during the day. Additionally, it is unlawful to use trawl nets from December 1 through February 28 from one hour after sunset to one hour before sunrise in portions of the Pamlico, Pungo, Bay, Neuse, and New rivers [15A NCAC 3J .0104 (b) (5)(A)(B)(C)(D)(E)]. This was originally put in place to protect juvenile southern flounder that were being harvested from crab trawls (K. West, NCDMF, personal communication).

In 1997, many Sneads Ferry trawl fishermen requested opening the New River to daytime shrimp trawling only. This was not based on any biological information. Many of the local shrimpers preferred to fish during the daytime and wanted to keep trawlers from neighboring areas out of New River at night. NCMFC Rule 15A NCAC 03J .0208, effective in 1998, makes it unlawful to use trawl nets upstream of the Highway 172 bridge over New River from 9:00 p.m. through 5:00 a.m. when opened by proclamation from August 16 through November 30.

TOW TIME RESTRICTIONS

Skimmer trawls are currently exempt from TED requirements in lieu of tow time restrictions (55 minutes from April to October and 75 minutes from March to November). However, beginning August 1, 2021 it is expected that skimmer trawls 40 feet and greater in length will be required to use a TED with a bar spacing of no more than three inches in each net. Skimmer trawl vessels under 40 feet will still be able to abide by the tow time restrictions in lieu of installing TEDs. Similarly, try nets are exempt from TED requirements in lieu of tow time restrictions (55 minutes and 75 minutes, seasonally). This exemption is also contingent on: 1) the net is pulled immediately in front of another net or is not connected to another net in any way, 2) no more than one net is used at a time, and 3) the net is not towed as a primary net.

TRIP/CREEL LIMITS

Currently, there are no trip limits for the commercial shrimp fishery. However, there are creel limits for the recreational shrimp fishery. In areas open to shrimp harvest, recreational fishermen are limited to no more than 48 quarts (heads on) or 30 quarts (heads off) of shrimp per person per day or per vessel per day if a vessel is used [NCMFC Rule 15A NCAC 03L .0105(1)]. However, if more than one RCGL holder is aboard a vessel they are limited to no more than 96 quarts (heads on) or 60 quarts (heads off) of shrimp per vessel per day [NCMFC Rule 15A NCAC 03O .0303(e)(f)]. In areas closed to the harvest of shrimp, no more than four quarts (heads on) or two and one-half quarts (heads off) of shrimp per person per day may be taken by cast net only [NCMFC Rule 15A NCAC 03L .0105(2)]. Although it should be noted no areas are completely closed to shrimp harvest, however, enforcement of this rule has used the areas closed to taking shrimp with nets as defined in proclamation as areas closed to the taking of shrimp under this rule.

OTHER GEARS

In addition to trawls, several other gears are used to harvest shrimp, these include but are not limited to channel nets, seines, cast nets, shrimp pots, and shrimp pounds. Current management measures, implemented through proclamation, restrict the commercial and recreational harvest of shrimp (therefore effort) with nets to shrimp trawls, crab trawls, seines, and cast nets to specific areas and times. Areas are open to harvest with seines and cast nets at the same time they open to shrimp and crab trawls, so the use of these non-trawl nets is limited to when areas are opened to trawling. The use of shrimp pounds, shrimp pots, channel nets, fyke nets, and other non-net gears used to harvest shrimp are not limited to areas and times open to shrimp trawls, crab trawls, seines, and cast nets. Harvest of shrimp with other types of nets not specifically listed above (such as gill nets) is prohibited regardless of the area or time. These restrictions on harvest with other gears were primarily put in place due to issues of fairness over access to the shrimp resource raised by shrimp trawl fishermen as well as some fishermen wanting to delay harvest of shrimp until they were larger and more valuable.

Channel nets are also managed with area closures (Proclamation M-10-2007). Permanently closed areas are: 1) all waters bound on the north by the site of the old N.C. Highway 210-50 swing bridge at Surf City and on the south by a line beginning on the east side of the Intracoastal Waterway (IWW) at 34° 25.6049' N, 77° 33.4116' W running to a point on the west side of the IWW at 34°

25.7193' N, 77° 33.4649' W to include all areas on either side of the IWW channel and 2) the New River marked navigation channel from Marker #17 to New River Inlet. While some areas are permanently closed to channel nets, others are closed unless they are open to shrimping with other gears by proclamation. These areas include: 1) New River above a line beginning at a point on the north shore 34° 34.9000'N – 77° 24.1740' W running southerly through Marker # 25 to a point on the south shore 34° 34.2700' N – 77° 24.4770' W, 2) areas adjacent to the IWW from the site of the old Highway 210-50 Surf City swing bridge to IWW Marker #49, and 3) the Cape Fear River. Closures (permanent or conditional) for channel nets were typically put in place to address user conflict issues.

AREA RESTRICTIONS

Area restrictions for trawling have been used to deal with allocation, resource, habitat, and safety issues in North Carolina. During the late 1980s trawling was prohibited in Albemarle Sound and its tributaries [15A NCAC 3J .0104 (b) (3)]. This action was implemented to protect the flounder fishery in this area (allocation issue) and to reduce conflicts with crab pot fishermen. Since 1978 over 124,000 acres of estuarine nursery areas have been closed to trawling to protect juvenile fish and crustaceans. NCMFC Rule 15A NCAC 3N .0102 (a) defines Nursery Areas "as those areas in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young fish and crustaceans spend the major portion of the initial growing season." There are approximately 77,000 acres of Primary Nurseries (PNAs), 47,000 acres of Secondary Nursery Areas (SNAs), and 37,000 of Special Secondary Nursery Areas (SSNAs). PNAs and SNAs are permanently closed to trawling, while SSNAs may only be opened to trawling by proclamation from August 16 through May 15. In the mid-1990s the seagrass beds along the Outer Banks were closed to trawling to protect this critical habitat. Over 78,000 acres of military danger zones and restricted areas are also closed to trawling for safety reasons. In all, approximately 47% of estuarine waters are closed to trawling, 4% are managed, and 49% are open. In state ocean waters, approximately 19% are closed, 1% are managed, and 80% are open to trawling. Although, it should be noted that not all these open, closed, and managed areas are ideal for shrimp trawling. For additional discussion of area closures for shrimp trawls see *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas* or *Appendix 2.3: Reducing Shrimp Trawl Bycatch Through Area Closures that Increase Connectivity Between Closed Areas.*

SEASON RESTRICTIONS

Harvest seasons have been used to reduce bycatch by relegating fishing activity to times of maximum target species abundance, or by limiting activity during times of high bycatch. Currently shrimp trawling is permitted all year in North Carolina. However, some areas are only opened to shrimp trawling for limited time periods. These include SSNAs, other managed shrimp trawl areas, and Crab Spawning Sanctuaries. For additional discussion of season closures see *Appendix 2.2: Shrimp Management in Special Secondary Nursery Areas* or *Appendix 2.3: Reducing Shrimp Trawl Bycatch Through Area Closures that Increase Connectivity Between Closed Areas.*

IV. AUTHORITY

North Carolina General Statutes
G.S. 113-134 RULES
G.S. 113-173 RECREATIONAL COMMERCIAL GEAR LICENSE
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 113-182.1 FISHERY MANAGEMENT PLANS
G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Commission Rules
15A NCAC 03J .0104 TRAWL NETS
15A NCAC 03L .0101 SHRIMP HARVEST RESTRICTIONS
15A NCAC 03L .0102 WEEKEND SHRIMPING PROHIBITED
15A NCAC 03L .0103 PROHIBITED NETS, MESH LENGTHS AND AREAS
15A NCAC 03L .0105 RECREATIONAL SHRIMP LIMITS

V. DISCUSSION

The management options presented in this paper are a starting point for discussion on reducing effort in the shrimp trawl fishery to limit or reduce bycatch. Public input could provide additional options.

Carry Forward Items from Amendment 1

There are a few effort reduction management measures that will be carried forward from Amendment 1 to the N.C Shrimp Fishery Management Plan. These include: 1) requiring shrimp trawls, with the exception of skimmer trawls, to use BRDs or gear configurations that reduce finfish bycatch by at least 40% over a standard shrimp trawl consisting of a Florida fisheye BRD, a federally approved TED, and a 1.5-inch mesh tailbag, 2) allowing any federally certified BRD to be used in areas where new BRD or gear configurations have not been established, and 3) requiring two approved BRDs to be used in shrimp trawls in areas where new BRD or gear configurations have not been established.

Limited Entry

Limited entry methods of management restrict access to a fishery. Capping or reducing fishing effort can protect the biological viability of a species and the economic integrity of the fishery. The species is protected by preventing overfishing and depletion of the stocks. The fishery is enhanced by reducing costs and increasing earnings, effectively increasing efficiency. Other benefits of limited entry programs include an incentive to conserve, more efficient management, bycatch minimization, and habitat protection. However, piecemeal implementation of limited entry programs can easily displace fishing effort from one fishery to create new problems in other areas and fisheries (Buck 1995). For bycatch reduction, limited entry systems are often used in conjunction with other management measures, such as quotas or trip limits to achieve management objectives.

North Carolina General Statute 113-182.1 states the NCMFC can only recommend the General Assembly limit participation in a fishery if the commission determines sustainable harvest in the fishery cannot otherwise be achieved. As shrimp in North Carolina are managed as an annual crop, due to the strong influence of environmental factors on population size, sustainable harvest is not currently a concern. Therefore, limited entry is not considered a realistic option for managing shrimp at this point due to the statutory constraints on its use. However, several bycatch species in the shrimp trawl fishery are currently classified as either overfished, overfishing is occurring, or both (e.g., weakfish and southern flounder). An amended state FMP for southern flounder (NCDMF 2019) has recently been adopted to recover the stock. Weakfish (ASMFC 2002, 2009a) is an interjurisdictional stock managed by the ASMFC and has an FMP in place to monitor and recover the stock. If it chose to do so, the NCMFC may ask the legislature to limit participation in the shrimp trawl fishery to potentially reduce bycatch of these species. To be effective in reducing bycatch, any limited entry program should not simply "freeze" participation in the shrimp trawl fishery to those currently in the fishery. It would have to reduce the number of participants/vessels to some number below those currently in the shrimp trawl fishery. Although, no clear link has been established between shrimp trawl discards and the status of these species and it will be impossible to attribute any population increases of these species with this type of action due to the many unpredictable human and natural factors that affect fish stock abundance.

If the areas where shrimp trawls can be used are significantly reduced, then limited entry may become more important as fishing effort will become concentrated in smaller areas. This concentration of effort may increase the detrimental effects on the habitat and bycatch species in those areas that remain open. It may also lead to increased conflict among fishermen in these areas competing for resources in limited space.

NCDMF Shrimp Trawl Observer Data Analysis

In order to determine if any trawl gear parameters influenced the catch rate of bycatch in otter and skimmer trawls, NCDMF shrimp trawl observer data from 2012 through 2017 were examined using two different modelling approaches, catch-per-unit-effort (CPUE) and presence/absence models. Observations from 1,567 individual tows were used in the analyses. The results of the analyses generally varied depending on the species or species group included in the model as well as how areas were delineated in the different model scenarios (see *Appendix 2.4.A: Shrimp Trawl Bycatch Effort Analysis* for more details).

There was some variation in the significant predictor variables dependent on the species or species group, scenario, and sub-model. For example, for the CPUE sub-model, there are consistent results for multiple species and species groups across scenarios. Specifically, of the 65 possible combinations of scenarios and species or species groups; year, net type, and season are significant for 80%, 66%, and 52% of the sub-models. Gear parameters such as headrope per boat, wing mesh, and tailbag mesh were not significant factors in any of the CPUE sub-models, however, potentially valuable species-specific information was still extracted from the analysis. For example, spot and weakfish were encountered in shrimp trawls more frequently than other key bycatch species, present in 93% and 54%, respectively, of all trawl samples and present in 99% and 73%, respectively, in trawl samples from Pamlico Sound where the majority of estuarine shrimp harvest and effort occurs. For spot, net type was a significant factor in the 3-area (Pamlico, inshore, offshore), 2-area (inshore, offshore), and inshore models with tongue style nets having more spot bycatch than two-seam and four-seam nets. Similarly, net type was also a significant factor for weakfish in the 3-area, 2-area, inshore, offshore, and Pamlico models with tongue nets having more weakfish bycatch. While not entirely surprising, this does suggest net type may be important to consider when discussing gear modifications to reduce bycatch for these species. Season was also consistently a significant factor for weakfish in all models. With summer having higher rates of weakfish bycatch in the 3-area, 2-area, inshore, and offshore models, and the fall having higher rates of weakfish bycatch in the Pamlico model. This suggests for weakfish that season should be considered when discussing methods to reduce weakfish bycatch and that one approach may not work for all areas.

The presence/absence sub-models provided less clearly distinct generalizations yet, there is still valuable species-specific information. In the presence/absence models used for zero-inflated species (those with high numbers of zero catches), total headrope per boat (summer flounder), wing mesh size (Atlantic croaker and summer flounder), and tailbag mesh size (summer flounder) were selected as significant factors and may provide some direction for future research.

Due to the onboard observations being made opportunistically and inconsistently across years, months, and areas many had few or no observations. Modelling efforts were further hampered by the high number of zero catches for some species as well as variations in the level of data collected for each tow. Due to these limitations the results should be viewed as exploratory and inconclusive. However, some factors were repeatedly selected as significant among models including year, net type (typically indicating increased bycatch in tongue nets), and season (typically indicated increased bycatch in the fall). Although the results of these analyses are inconclusive, it does provide some direction for future research efforts. The significant data gaps also highlight the need for consistent monitoring of discards in the shrimp trawl fishery through a dedicated onboard observer program. This will allow managers to better quantify shrimp trawl bycatch and its impact on bycatch species as well as provide additional data that can be used to research and implement more constructive and focused means to reduce bycatch in the shrimp trawl fishery.

Headrope Limit

In early 2020, the NCDMF surveyed active shrimp trawlers to gather information on the characteristics of gear currently used in the shrimp trawl fishery. Of the 521 active shrimp trawlers, headrope length data were received for 212 gear configurations (197 otter and 15 skimmer) from 146 shrimp trawlers (135 otter and 11 skimmer) active in the shrimp trawl fishery. The headrope data came from a representative cross section of the shrimp trawl fishery. The highest percentage of vessels in the shrimp otter and skimmer trawl fleets occur in the 20-29-ft vessel size category and likewise survey responses were highest from this group (Figures 2.4.15 and 2.4.16). For both the otter trawl (Figure 2.4.17) and skimmer trawl (Figure 2.4.18) fleets, the total amount of headrope fished increased with vessel size. Vessels 60 ft and greater in length were found to fish up to the maximum amount of headrope allowed to be fished (220 ft in Pamlico Sound), though not all vessels do so. The median total amount of headrope fished by vessels in the 60-ft category was 180 ft, 200 ft in the 70-ft category, and 220 ft in both the 80 and 90-ft categories. The most common net type being fished by the shrimp trawl fleet is tongue nets (51%), followed by two-seam (25%), four-seam (16%), and skimmer (7%; Figure 2.4.19).

In the analysis of NCDMF shrimp trawl observer data (described above), total headrope per boat was not a significant factor influencing the amount of bycatch in any of the CPUE sub-models. In the presence/absence models used for zero-inflated species, total headrope per boat was a significant factor influencing bycatch of summer flounder. This analysis suggests the effects of total headrope per boat on bycatch catch rates may be an important factor for some species and should be investigated further.

Shrimp trawl design has evolved to improve the efficiency of the gear to capture shrimp and maximize area swept. Regulations limiting total headrope length will likely reduce the efficiency of both large and small vessels using trawls with headropes larger than 35 ft. Thus, overall effort will likely be reduced due to a loss of fishing power and fishermen leaving the fishery because it is no longer economically feasible. Not only will the current gear configuration used by many fishermen become obsolete, but operating costs may begin to exceed the value of their catch. Shifts in effort may also occur putting more pressure on already overburdened fishing locations, leading to increased conflict and potentially local increases in bycatch. Fishermen attempting to compensate for lost catches because of being forced to use less efficient gear may make more or longer tows, potentially generating as much or more bycatch. Reductions in bycatch may also be minimal if crews of larger vessels begin operating multiple smaller vessels, not only increasing effort (participants and trips) but the total amount of headrope being fished by the fleet. Additionally, some fishermen may begin towing at a faster speed to attempt to cover more area or increase the depth (height) of their nets to maintain shrimp numbers. This could increase bycatch by reducing the efficiency of existing BRDs. There is also the potential for shifts in the species and size makeup of the bycatch. If larger vessels are forced out of the internal coastal waters into the ocean due to regulations that reduce total headrope length, more pressure may be put on the winter ocean spawners (e.g., spot, Atlantic croaker, sheepshead, and southern flounder). While reducing headrope length has the potential to reduce bycatch associated with inshore trawling (Watson et al. 1984), the issue is extremely complex making it difficult to quantify its total impact on bycatch species and the fishery beyond a reduction in effort.

If the areas where shrimp trawls can be used are significantly reduced, then reducing the amount of headrope allowed in Internal Coastal Waters may be needed as fishing effort will be further concentrated into smaller areas. This concentration of effort may have detrimental effects on the habitat and bycatch species in those areas. It may also lead to increased conflict among fishermen in these areas competing for resources in limited space.

Otter Trawl Headrope/Footrope Regulations in Other States

All states in the U.S. South Atlantic have enacted various regulations limiting maximum headrope length, which often varies by area, fleet (commercial or recreational), and purpose (food or bait; Appendix 4). Estuarine trawling is prohibited in much of South Carolina; however, in designated areas fishermen may use shrimp trawls with a combined footrope length no greater than 220 ft. In Georgia, it is unlawful to fish for shrimp for human consumption with trawls having a total footrope length greater than 220 ft (only allowed in state ocean waters) and commercial and recreational bait shrimpers are restricted to trawls with maximum footrope lengths of 20 ft and 10 ft, respectively in designated bait shrimp areas. In the nearshore and inshore waters of Florida where otter trawls are allowed, fishermen are limited to a single net with a headrope no greater than 10 ft. Two trawls may be used in certain nearshore and inshore regions, however combined headrope length cannot exceed 20 ft. Outside of these areas trawlers may use a single net with headrope no greater than 20 ft.

States along the Gulf of Mexico have also limited the maximum headrope length and the number of nets fishermen can use (Appendix 4) typically to address conflict issues within the fishery. In Alabama, commercial vessels operating in Mobile Bay and its sounds are limited to two trawls with a maximum combined headrope length of 50 ft. In the offshore waters of Alabama there is no restriction on headrope length. Commercial and recreational bait trawlers are restricted to a single trawl with a maximum headrope length of 16 ft. In Mississippi, commercial shrimp trawlers operating in internal waters can use one trawl with a maximum headrope length of 50 ft or two 25 ft trawls. Recreational fishermen are limited to a 16 ft maximum headrope length. Commercial vessels fishing inshore waters of Louisiana are limited to one net with a headrope length of 50 ft or two 25 ft nets [except in Breton and Chandeleur sounds two nets with a headrope length of 65 ft (130 ft combined) may be used]. Vessels fishing in Louisiana's state ocean waters may use up to 130 ft of headrope. Recreational fishermen are limited to one net with a maximum headrope length of 25 ft. In major bays of Texas, commercial fishermen targeting penaeid shrimp may use a single net with a headrope measuring 40 to 54 ft during the spring (statewide) and winter (south of the Colorado River) seasons and may use a single net with a headrope not exceeding 95 ft during the fall season. Commercial bait fishermen are also limited to a single net with a headrope measuring 40 to 54 ft. Commercial vessels operating in Texas state ocean waters may use two trawls with headrope lengths ranging from 71 to 89 ft based on door size inside three nautical miles and are not limited by number of nets or headrope from three to nine nautical miles offshore.

<u>Skimmer Trawl Headrope Regulations in Other States</u>

While headrope length is most associated with otter trawls, headrope length can also be used to describe the length of the support structure the mesh or webbing attaches to nearest the surface of the water for skimmer trawls. Thus, the headrope length of most skimmer trawls is dictated by the length of the skimmer trawl frame. Very few states have specific regulations for skimmer trawl configuration regarding headrope length and design (Appendix 4). Mississippi's skimmer trawl regulations mirror their otter trawl regulations, limiting vessels to two nets with a 25 ft headrope on each diagonal arm (not to exceed a combined headrope length of 50 ft). In Florida, skimmers must be equipped with rollers and vessels are limited to two unconnected trawls with upper and lower horizontal beams that do not exceed 16 ft in length each net. In most states where skimmer trawl net and frame lengths are not specified, headrope length is defined to include the length of supporting structure that is the nearest to the surface of the water.

Fishing Days Restriction

Adding additional day(s) of the week to the present closed trawling period is another time related bycatch reduction measure to consider. Although an additional day added to the weekend closure, be it Friday or Monday, would reduce shrimp trawling effort, it is not possible to quantify the reduction in bycatch. A uniform number of shrimp, as well as bycatch species, are not caught each available trawling day so an additional closed day may not reduce bycatch significantly.

Regardless of the day(s) of the week closed, it has been observed the best catches of shrimp are on the night of the opening after the weekend "rest period". Johnson (2006) noted twice as much shrimp were caught early in the five-day trawling week than later in the week in the coastal shrimp trawl fishery in NC, suggesting extending the weekly closure could further improve the efficiency of the shrimp trawl fishery. Extending the weekend closure would likely reduce effort; however, reducing the number of days available for shrimp trawling does not consider days already lost to wind and weather, unfavorable tides, moon phases, etc. Additional day(s) added to the weekend closure may also disproportionally impact RCGL holders and part-time fishermen who shrimp trawl mainly around the weekends.

Daily Fishing Time Restriction

Reducing the number of hours in a day when shrimp trawling is allowed is another way to potentially reduce bycatch. The habits of North Carolina's three shrimp species determine when they are targeted. In the central part of the state, brown and pink shrimp usually burrow into the substrate during the day and trawling for them usually occurs at night. Occasionally trawling for brown shrimp can occur during the daytime when waters are murky. These trips usually last one night or one day. Larger trawlers fishing in Pamlico Sound and the Atlantic Ocean with the capacity to store ice usually stay out four or five days and tow day and night. White shrimp are found higher up in the water column and fishing for them occurs mainly during the day with some fishing at night as well.

South Carolina shrimp trawling has been closed at night since the 1970s, but that was enacted to keep North Carolina fishermen from catching brown shrimp at night because South Carolina fishermen wanted to work during the day, not for any biological reason (L. DeLancey, SCDNR, personal communication). Georgia, Mississippi, Louisiana, and Texas also close all or parts of their shrimp trawl fisheries to nighttime trawling (Appendix 4).

Tow Time Restriction

Another way to potentially reduce effort in the shrimp trawl fishery is to restrict individual tow times. A tow time limit of 45 minutes has been mentioned by the public. Although reducing tow times should logically reduce bycatch, in reality that may not necessarily occur as additional tows could be made and result in minimal reductions in the amount of time the trawl is actually fishing. Reduced tow times could likely reduce bycatch mortality for some species by allowing them to be released from the trawl more quickly. Fish aggregations, as well as shrimp aggregations, are not uniformly distributed and each tow is different depending on depth, tide stage, moon phase, bottom type, etc. Carothers and Chittendon (1985) found a significant linear relationship between catch and tow duration (i.e., the longer you tow, the more you catch). Their study examined the catch for tow times of 5, 10, 15, 20, 25, and 30-minute durations.

A tow time requirement would be very difficult to enforce without constant Marine Patrol oversight or costly Vessel Monitoring Systems. Tow times in the ocean were enforced from 1996 through 2005 under a now-expired Incidental Take Permit from NOAA issued to trawlers from Browns Inlet to Rich Inlet due to the presence of brown algae. This involved constant monitoring by observers and was very difficult to enforce. The timing of tows began when the otter trawl doors were lowered into the water and ended when they exited the water. Skimmer trawl tows could not be timed in that way since they are towed continuously and the tailbags are pulled in and emptied periodically. Additional tows could be made to make up for the "lost effort" of limited tow times. Although, limiting tow times may be effective in reducing bycatch mortality in individual tows.

Trip/Creel Limits

Another method of reducing effort is to establish commercial trip limits or recreational creel limits. The reasoning behind this method is the expectation that once the limit is reached fishermen will either cease fishing for the day or begin to target another species.

Commercial Fishery

In the commercial shrimp trawl fishery, establishing a trip limit may be effective in reducing overall shrimp trawl effort and therefore presumably reducing the amount of bycatch and dead discards. However, the limit would have to be high enough for a trip to still be profitable but low enough that the vessel would have to cease fishing operations for the day for single day trips or to return to port to offload their catch at least once during the weekly open period if capable of multi-day trips. Establishing vessel limits for annual crop species (such as shrimp) in high volume fisheries that can have large annual fluctuations in abundance due to environmental conditions can be difficult. Adding to the difficulty for shrimp in North Carolina is the wide range in the size of vessels and size of gear used in the fishery and the subsequent range in how many pounds can be stored onboard across vessel sizes. Establishing a trip limit that works for 40 ft vessels may not work for 80 ft vessels in terms of maintaining profitable trips. Waste would also be a potential issue if the trip limit were set too low given the high-volume nature of the fishery. Additionally, enforcement of this type of measure can be difficult to enforce without adequate assets in place (ASMFC 2009b).

Recreational Fishery

As previously discussed, the recreational fishery has different creel limits in place for areas open versus closed to shrimp harvest (keeping in mind no areas are completely closed to shrimp harvest). Increased access could be given to recreational fishermen in closed areas by allowing non-trawl net gears (i.e., seines and other non-trawl nets) to be used to harvest shrimp in areas closed to trawling, increasing the creel limit for closed areas, or both. With these gears, discards of bycatch species are not a big concern so allowing them would presumably have little negative impact on these species. Removing the four quarts (heads on) or two and one-half quarts (heads off) creel limit for cast nets in closed areas and allowing recreational harvest limited to 48 quarts (heads on) or 30 quarts (heads off) of shrimp per person per day or per vessel for all gears and areas would simplify regulations and allow additional harvest opportunities for recreational fishermen if additional areas are closed to shrimp trawls.

Other Gears

As previously stated, the reason for tying the opening of crab trawls, seines, and cast nets and prohibiting harvest with other nets (except for channel nets and fyke nets) with shrimp trawls was done primarily due to fairness issues raised by shrimp trawl fishermen. With the possibility of additional area and/or seasonal closures for shrimp trawls, severing the tie between when areas open to shrimp trawls versus other net gears would eliminate impacts to these gears from additional shrimp trawl closures. Additionally, fishermen holding a RCGL may have the use of shrimp trawl gear severely reduced if additional areas are closed to shrimp trawling (either permanently or seasonally). Having additional harvest opportunities using seines and cast nets may alleviate some of these impacts. Even if additional closures are not adopted for shrimp trawls, removing the connection between non-trawl gears and shrimp trawls will allow additional harvest opportunities for fishermen using these gears, simplify regulations, and ease confusion over what areas are open to which gears.

While some areas are permanently closed to channel nets, others are closed until they are opened to shrimp harvest with other gears. This has been enforced to mean when these areas are open to taking shrimp with nets as defined in proclamation. These areas include: 1) New River above a line beginning at a point on the north shore 34° 34.9000'N – 77° 24.1740' W running southerly through Marker # 25 to a point on the south shore 34° 34.2700' N – 77° 24.4770' W, 2) areas adjacent to the IWW from the site of the old Highway 210-50 Surf City swing bridge to IWW Marker #49, and 3) the Cape Fear River. Removing the dependency on other gears (i.e., shrimp trawls) for these areas to be opened to channel nets will allow increased access to channel net fishermen in these areas. This may be more desirable if the areas where shrimp trawls can be used are significantly reduced or the areas where channel net openings are dependent on other gears become permanently closed to shrimp trawls.

Economic Impacts

Each of the different management measures discussed in this paper would have economic impacts to the shrimp fishery with economic consequences for those operating and working on shrimp trawlers. Any reduction in effort will likely reduce the efficiency of the shrimp trawl fishery and consequently reduce the amount of shrimp harvested and likewise profitability of each trip. This may also lead to reduced employment in the shrimp trawl fishery as operators have to deal with tighter profit margins. However, there is also the possibility for economic gains in other portions of the shrimp fishery as well as other fisheries. Additional opportunities for recreational and commercial fishermen using non-trawl gears may lead to some economic gains for commercial fishermen using these gears and recreational fishery suppliers as fishermen purchase additional gear. Another potential benefit of reduced shrimp trawl effort may be improved habitat and reduced bycatch mortality (hence increased survival) of bycatch and other species and thus have more available for harvest as recruits grow into the fishery (both commercially and recreationally). Additionally, improved habitat may also improve other economic niches like eco-tourism. Although, these types of economic benefits are more abstract, uncertain, and dependent on other external factors.

Summary

While the management measures presented here have the potential to reduce effort and presumably bycatch and dead discards in the shrimp fishery, the necessary data do not exist to adequately quantify the full impact any of these regulations may have on bycatch reduction and survival as well as on the shrimp fishery and its associated industries. Limited entry would be difficult to implement with the current statutory restrictions but may need to be explored depending on other management measures enacted in this or future FMPs. While no clear connection between headrope length and bycatch has been established, this measure may warrant consideration if the areas open to shrimp trawling are significantly reduced. Reducing the number of days open to shrimp trawling would have some reduction on effort but may disproportionally impact part-time and RCGL fishermen. Daily fishing time restrictions may also reduce effort and would likely impact boats that make multi-day trips. Limiting tow times would likely reduce bycatch mortality but is difficult to enforce. Establishing commercial trip limits may also reduce effort but determining an appropriate trip limit that balances ecological and economic considerations will be difficult. Simplifying recreational creel limits will aid both the fishing public and enforcement actions. Additionally, removing the dependency of other gears on shrimp trawls will help to simplify regulations and potentially create additional opportunities for non-trawl gears. Ultimately, the decision to be weighed will be the potential unquantified gain in some bycatch species versus the losses to an economically important fishery.

VI. PROPOSED MANAGEMENT OPTIONS

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

1. Status quo: no additional management changes at this time
   + No additional management changes for fishermen to learn
   - No additional reductions in bycatch
   - Continues disparity between rules and management practices

2. Request the N.C. General Assembly consider limited entry as a means to manage the shrimp trawl fishery
   + Most effective way to limit effort in the shrimp trawl fishery
   - Current participants may be excluded from the fishery moving forward

3. Reduce the total amount of trawl headrope that may be used per vessel to harvest shrimp in Internal Coastal Waters
   + May reduce bycatch
   - Effort may increase to make up for loss of efficiency/fishing power
   - Possible financial hardships for fishermen due to loss of fishing power, gear modification, further distance from fishing grounds where headrope limits not imposed
   - May shift effort offshore and further impact other species and/or age classes

4. Reduce the number of days per week shrimp may be harvested using trawls in Internal Coastal Waters
   + May reduce bycatch
   + Easy to enforce
   - Effort may increase to make up for loss of fishing days
   - Additional days may be lost due to wind and weather, unfavorable tides, moon phases

- May impact RCGL holders and part-time fishermen disproportionally
- May force fishermen to work in unfavorable conditions
- May increase conflict in more productive areas

5. Reduce the number of hours during the day trawls may be used to harvest shrimp in Internal Coastal Waters
   + May reduce bycatch
   - May negatively impact the harvest of brown and pink shrimp
   - May force fishermen to work in unfavorable conditions
   - Increased enforcement (maybe?)

6. Establish a maximum tow time for trawls being used to harvest shrimp in Internal Coastal Waters
   + Increased survivability of culled bycatch
   - Hard to enforce / increased enforcement
   - Reductions in bycatch offset by additional tows
   - Loss of fishing time due to more haul backs

7. Establish a trip limit for the commercial shrimp trawl fishery in Internal Coastal Waters
   + May reduce bycatch
   - May create waste or encourage high grading

8. Eliminate the four quarts (heads-on) or two and one-half quarts (heads-off) recreational creel limit for cast nets only in areas closed to shrimping and allow recreational harvest limits in closed areas to be the same as open areas for all gears
   + Increased access to the resource (bait, consumption)
   + Eliminates confusion over creel limits
   - May increase conflict between recreational and commercial fishermen

9. Allow non-trawl gears (e.g., seines, channel nets, shrimp pots, shrimp pounds, cast nets, etc.) to harvest shrimp in areas closed to shrimp trawling
   + Encourages the use of non-bottom distributing gears with less bycatch
   + Increased access to the resource
   + Eliminates confusion over what areas are open to shrimp harvest for non-trawl gears
   - Increased conflict over set locations and navigation issues with channel nets

VII. SHRIMP FMP WORKSHOPS

Shrimp FMP Workshops were held in March 2021 between the division plan development team and the Shrimp FMP Advisory Committee (AC). The goal of these workshops is for the AC to assist the division in drafting the plan. The division had distinct discussion points to lead conversation to inform individual issue papers where stakeholder input was needed. The guidance received during workshops on enforcement, gear usage, possible industry behavioral changes, fishing times, and harvest limits were used to inform the draft plan. Some AC members indicated how they fish is less important to bycatch than where and when they fish. Additionally, industry behavior will change if certain measures in this issue paper are put in place. Support was mixed on management measures regarding recreational harvest limits and increased access for non-trawl gears.

VIII. RECOMMENDATION

The division will make recommendations after receiving input from the MFC Advisory Committees.

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Tables

Table 2.4.1. Summary of North Carolina commercial shrimp trawl characterization studies performed by the division, 2007-2017.

				Species							
	Study Details		Bycatch Characteristics	Atlantic croaker	spot	weakfish	blue crab	southern flounder	sheepshead	protected species	
Study 1	Study Period	7/2007 – 6/2008	Percent of Catch	25%	7%	2%	<1%	<1%	<1%	sea turtles	3
	Area Fished	Ocean	Size Range	120 – 180 mm	90 – 140 mm	50 – 305 mm	-	<355 mm	-	Atlantic sturgeon	0
Brown	Fishing Days Observed	143 (trips)	At-net Mortality	n/a	n/a	n/a	n/a	n/a	n/a	marine mammals	0
2009	Trawl Type	Otter								birds	0
	Number of Tows Sampled	314									
Study 2	Study Period	7/2009 – 12/2009	Percent of Catch	33%	13%	6%	2%	<1%	0%	sea turtles	0
	Area Fished	Pamlico Sound	Size Range	100 – 140 mm	80 – 120 mm	70 – 150 mm	-	130 – 180 mm	n/a	Atlantic sturgeon	0
Brown	Fishing Days Observed	66 (trips)	At-net Mortality	n/a	n/a	n/a	n/a	n/a	n/a	marine mammals	0
2010	Trawl Type	Otter								birds	0
	Number of Tows Sampled	191									
Study 3	Study Period	8/2012 – 8/2015	Percent of Catch	34 – 49%	10 – 21%	2%	<1 – 2%	<1 – 2%	<1%	sea turtles	1
	Area Fished	Estuary and Ocean	Size Range	100 – 170 mm	80 – 120 mm	70 – 180 mm	-	100 – 300 mm	-	Atlantic sturgeon	0
Brown	Fishing Days Observed	388	At-net Mortality	23%	66%	87%	-	0 – 88%	-	marine mammals	0
2015	Trawl Type	Otter								birds	0
	Number of Tows Sampled	1,037									
Study 4	Study Period	1/2015 – 11/2015	Percent of Catch	5%	1%	1%	2%	<1%	<1%	sea turtles	4
	Area Fished	Estuary	Size Range	100 – 180 mm	60 – 110 mm	140 – 210 mm	-	80 – 130 mm	-	Atlantic sturgeon	0
Brown	Fishing Days Observed	62	At-net Mortality	41%	82%	97%	-		-	marine mammals	0
2016	Trawl Type	Skimmer								birds	1
	Number of Tows Sampled	238									
Study 5	Study Period	1/2016 – 12/2016	Percent of Catch	8 – 27%	1 – 11%	<1 – 4%	<1%	<1%	0 - <1%	sea turtles	4
	Area Fished	Estuary and Ocean	Size Range	70 – 180 mm	60 – 190 mm	80 – 190 mm	-	-	-	Atlantic sturgeon	2
Brown	Fishing Days Observed	72	At-net Mortality	21%	77%	100%	-	-	-	marine mammals	0
2017	Trawl Type	Otter and Skimmer								birds	0
	Number of Tows Sampled	218									
Study 6	Study Period	7/2017 – 12/2017	Percent of Catch	6 – 35%	1 – 7%	<1 – 6%	<1 – 3%	<1 – 1%	0 - <1%	sea turtles	1
	Area Fished	Estuary and Ocean	Size Range	100 – 170 mm	70 – 210 mm	-	-	-	-	Atlantic sturgeon	0
Brown	Fishing Days Observed	25	At-net Mortality	24 – 33%	n/a	-	-	-	-	marine mammals	0
2018	Trawl Type	Otter and Skimmer								birds	0
	Number of Tows Sampled	70									

Figures

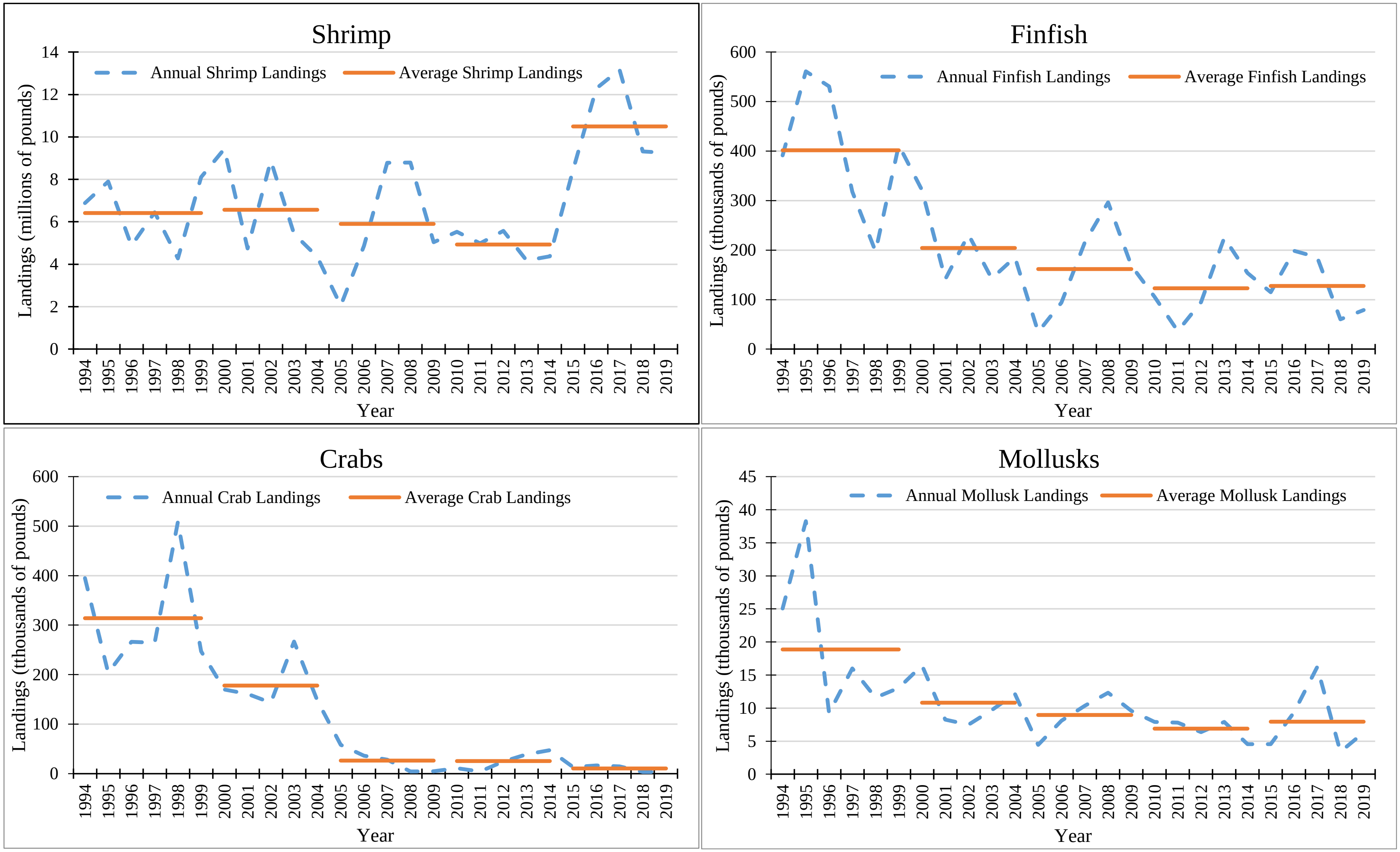


Figure 2.4.2. Annual landings (dashed line) and average landings (solid lines) of shrimp and incidental landings of finfish, crab, and mollusks from the commercial shrimp trawl fishery, 1994-2019. Note: the solid lines represent the average landings for the period covered.

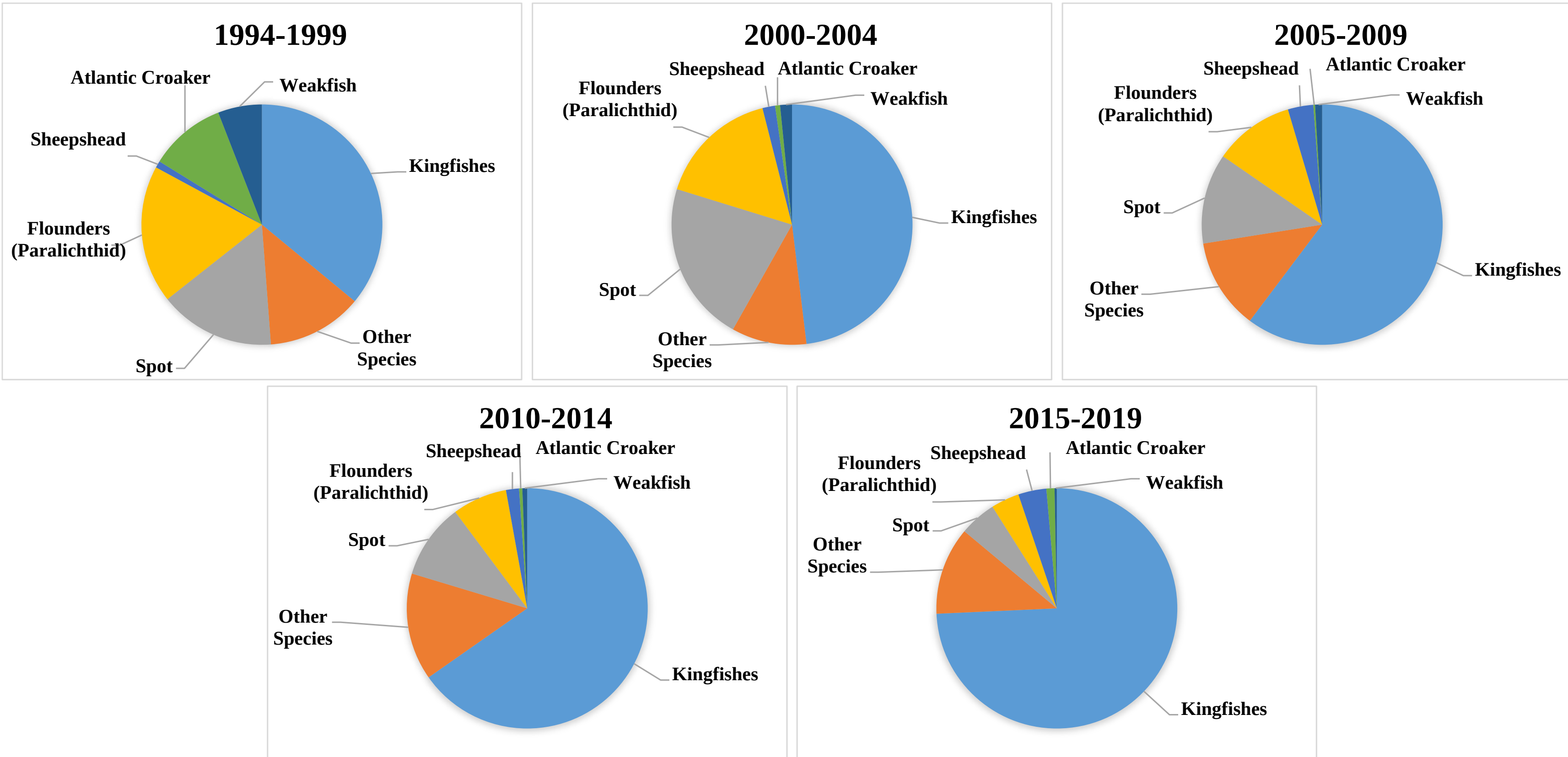


Figure 2.4.3. Proportional species makeup of incidental finfish landings in the shrimp trawl fishery for different periods, 1994-2019.

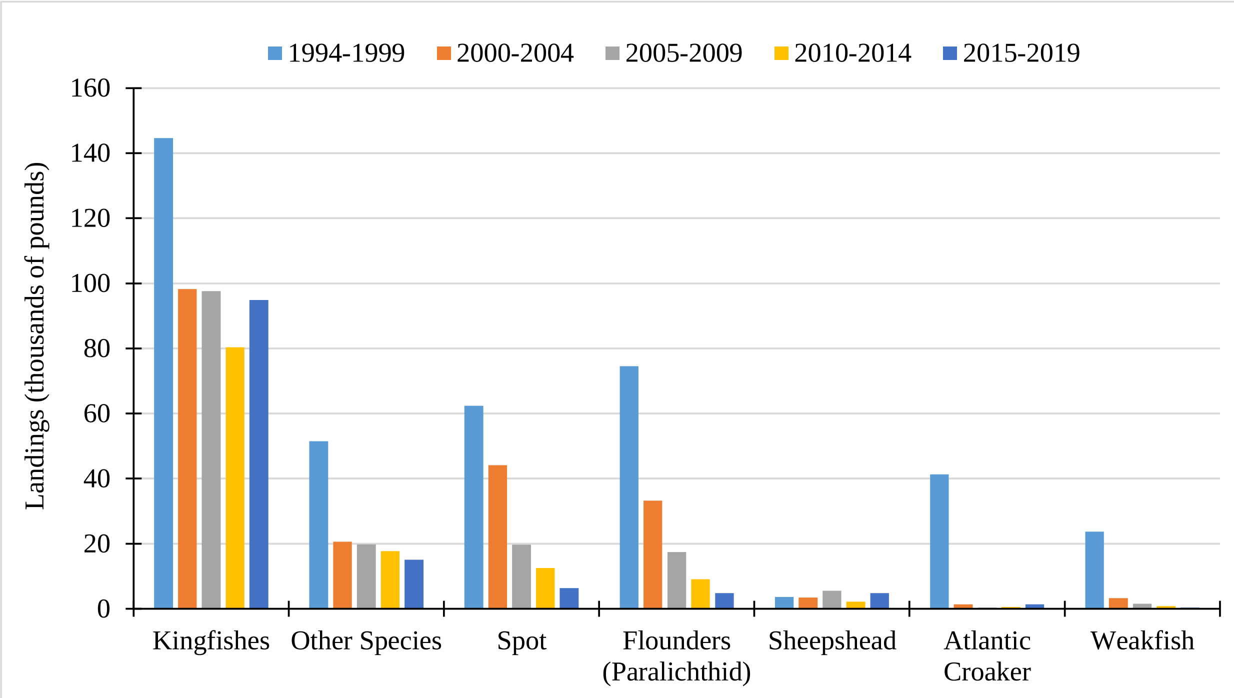


Figure 2.4.4. Average incidental landings of finfish species in the shrimp trawl fishery for different periods, 1994-2019.

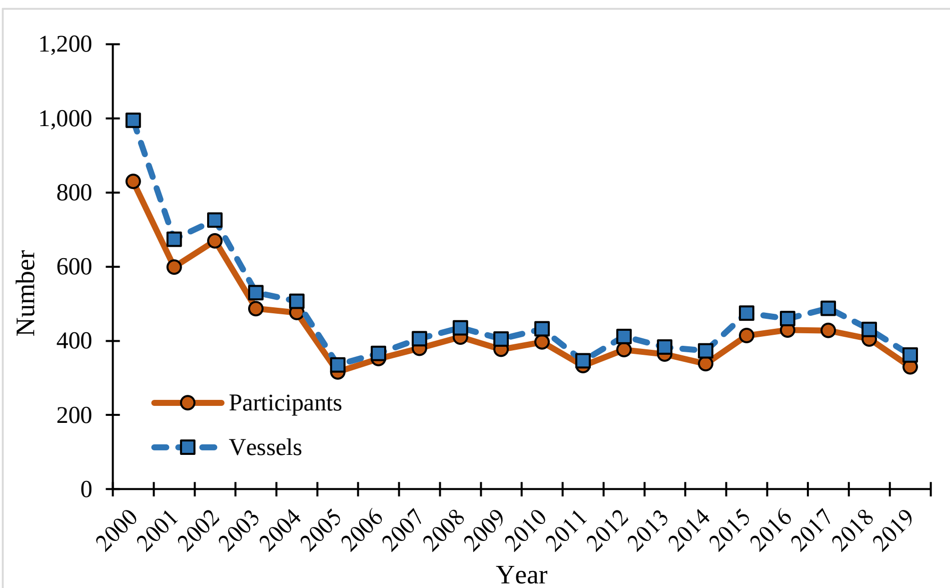


Figure 2.4.5. Number of participants and number of vessels in the North Carolina shrimp otter trawl fishery by year, 2000 – 2019.

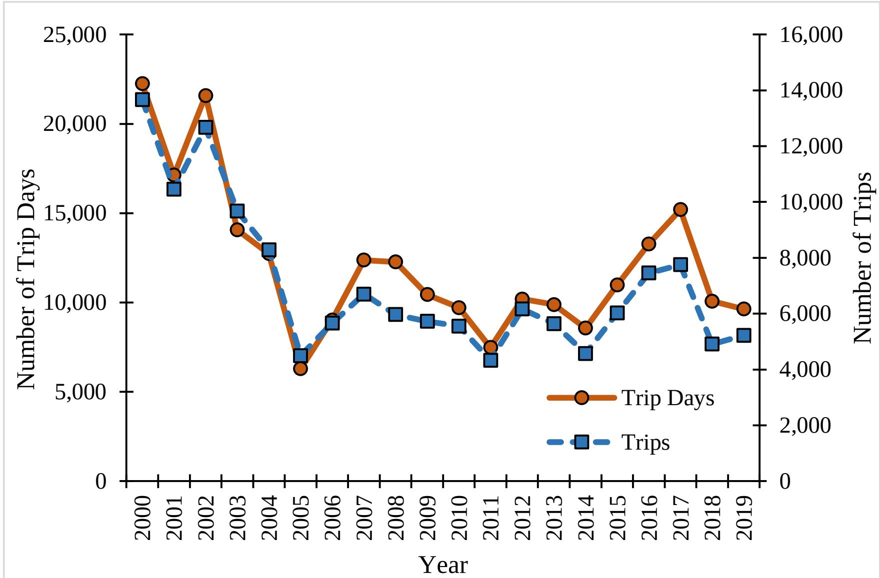


Figure 2.4.6. Number of trip days (number of trips x trip duration) and number of trips in the North Carolina shrimp otter trawl fishery by year, 2000 – 2019.

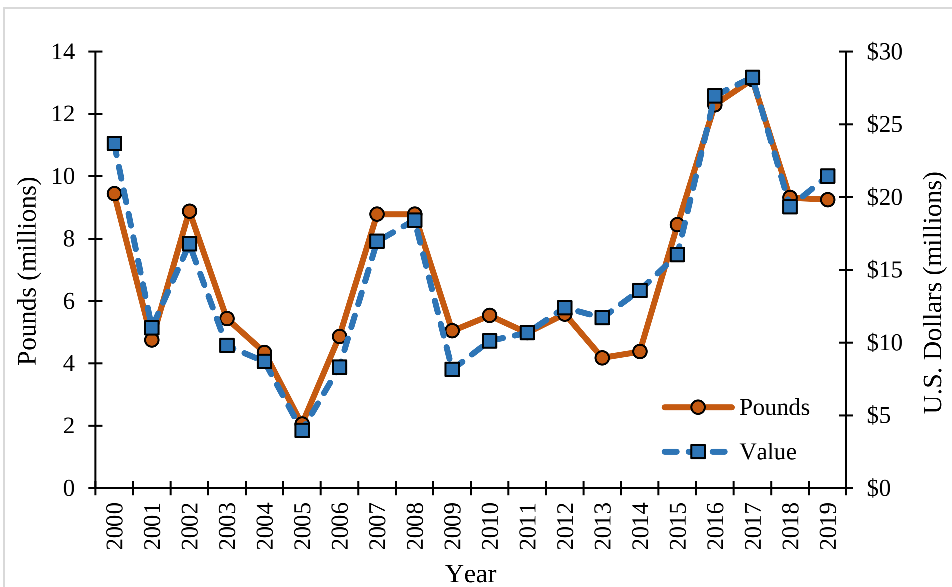


Figure 2.4.7. Pounds of shrimp landed and value for the North Carolina shrimp otter trawl fishery by year, 2000 – 2019.

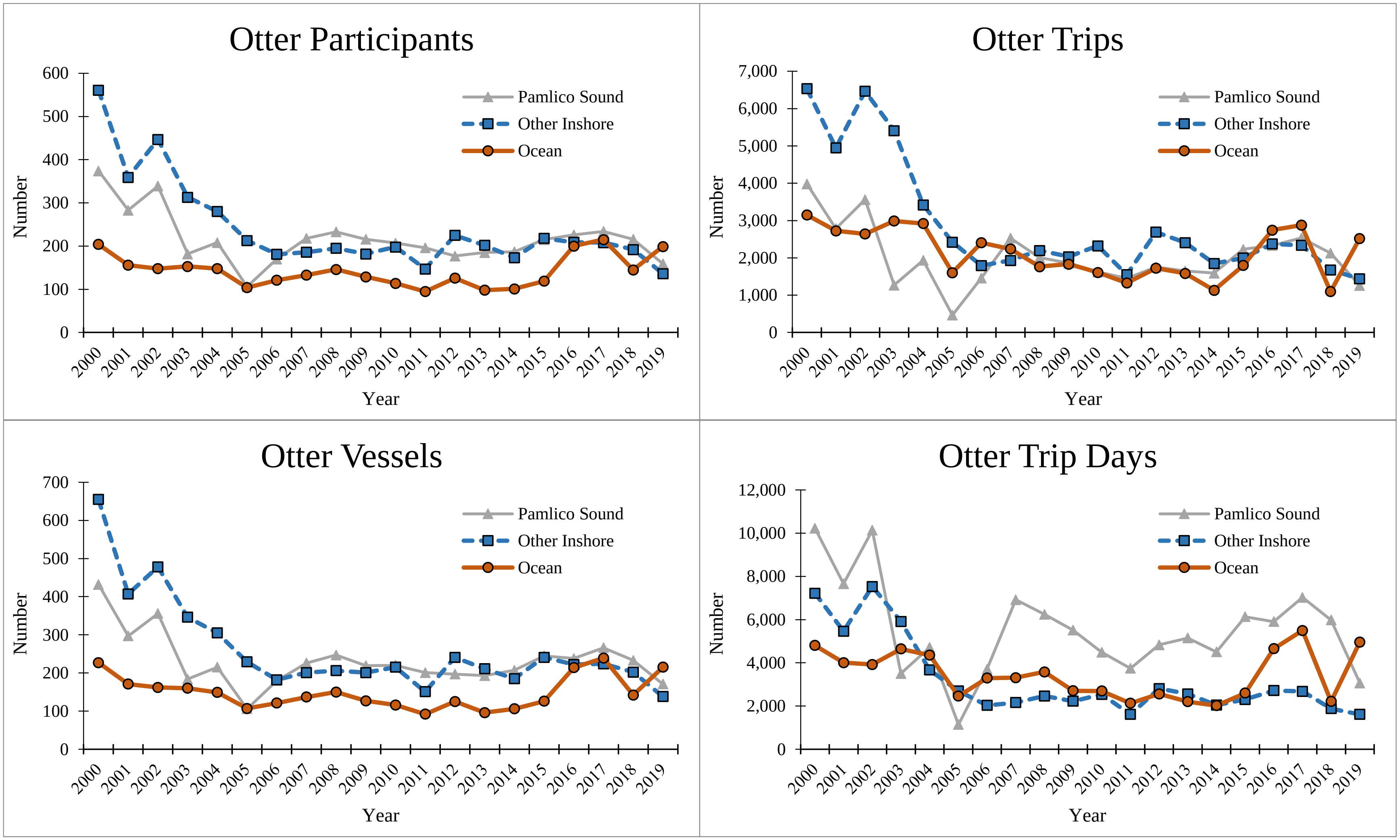


Figure 2.4.8. Number of participants, vessels, trips, and trip days by area for the North Carolina shrimp otter trawl fishery by year, 2000-2019.

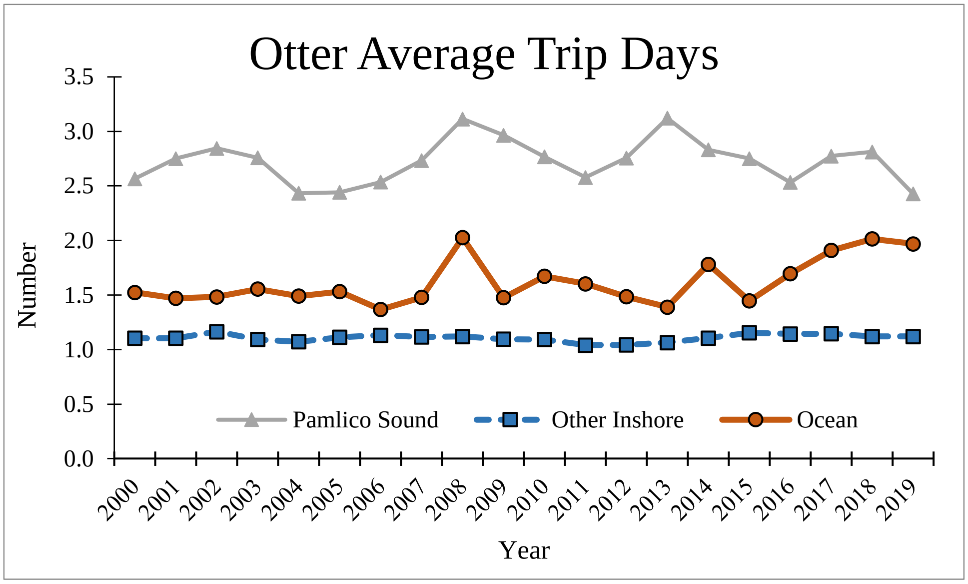


Figure 2.4.9. Average number of trip days by area for the North Carolina shrimp otter trawl fishery by year, 2000-2019.

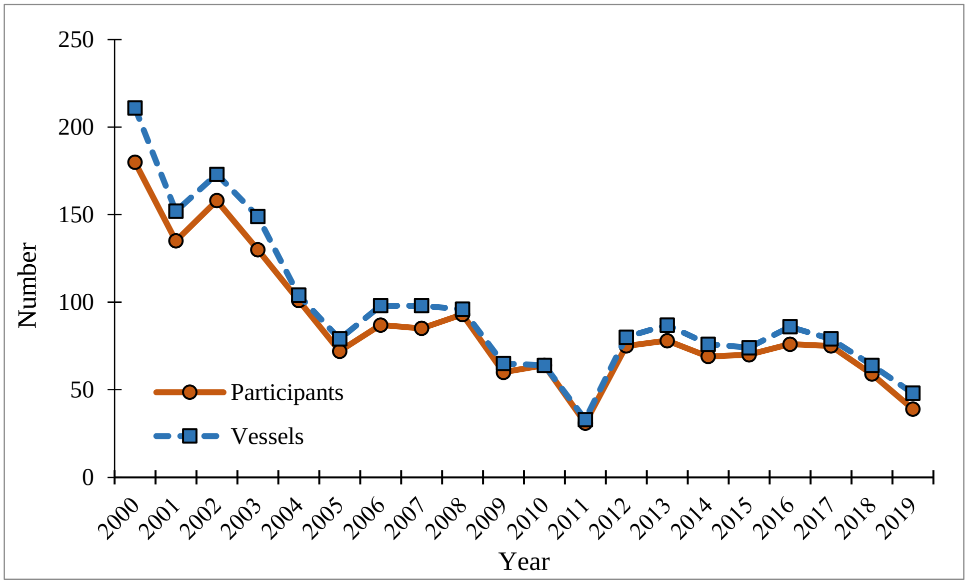


Figure 2.4.10. Number of participants and number of vessels in the North Carolina shrimp skimmer trawl fishery by year, 2000 – 2019.

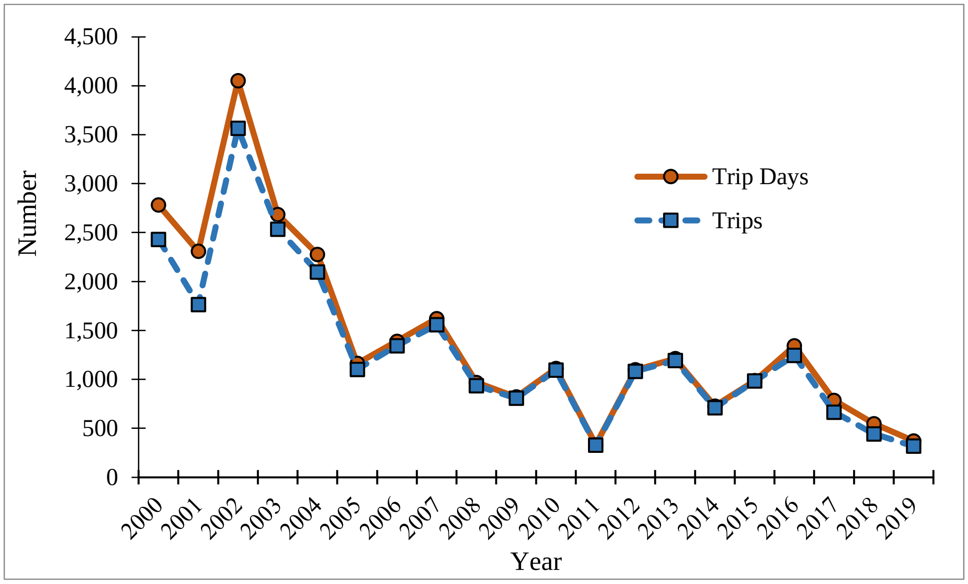


Figure 2.4.11. Number of trip days (number of trips x trip duration) and number of trips in the North Carolina shrimp skimmer trawl fishery by year, 2000 – 2019.

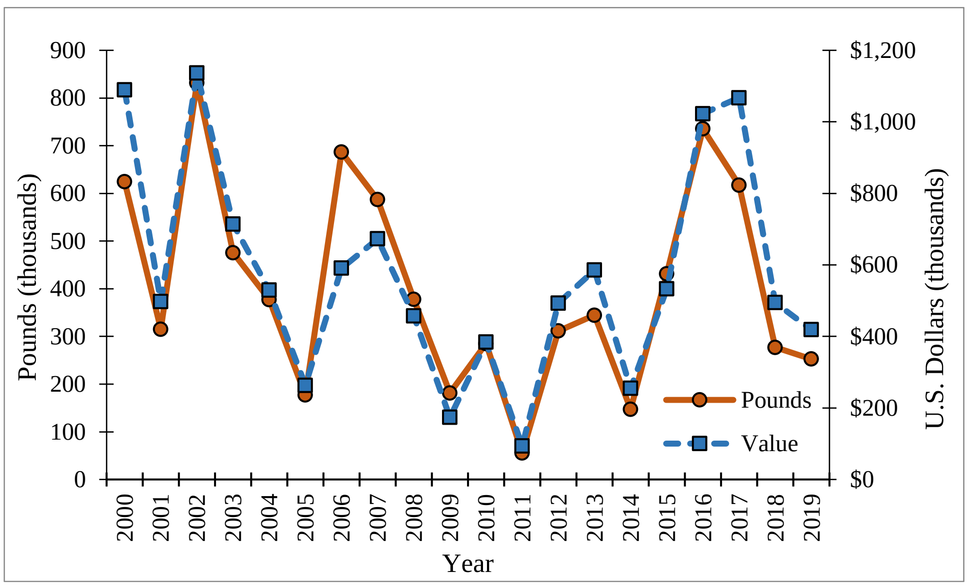


Figure 2.4.12. Pounds of shrimp landed and value for the North Carolina shrimp skimmer trawl fishery by year, 2000 – 2019.

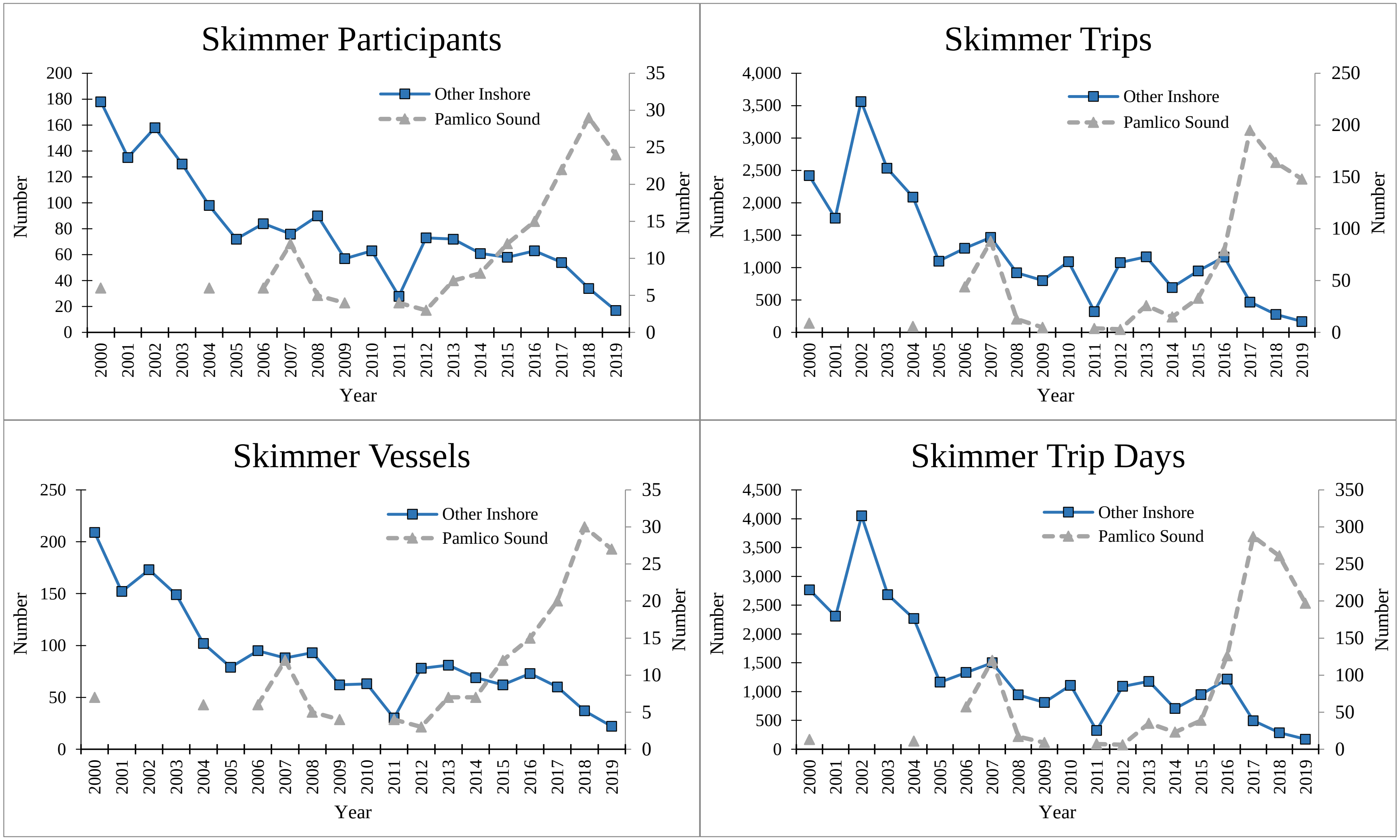


Figure 2.4.13. Number of participants, vessels, trips, and trip days by area for the North Carolina shrimp skimmer trawl fishery by year, 2000-2019.

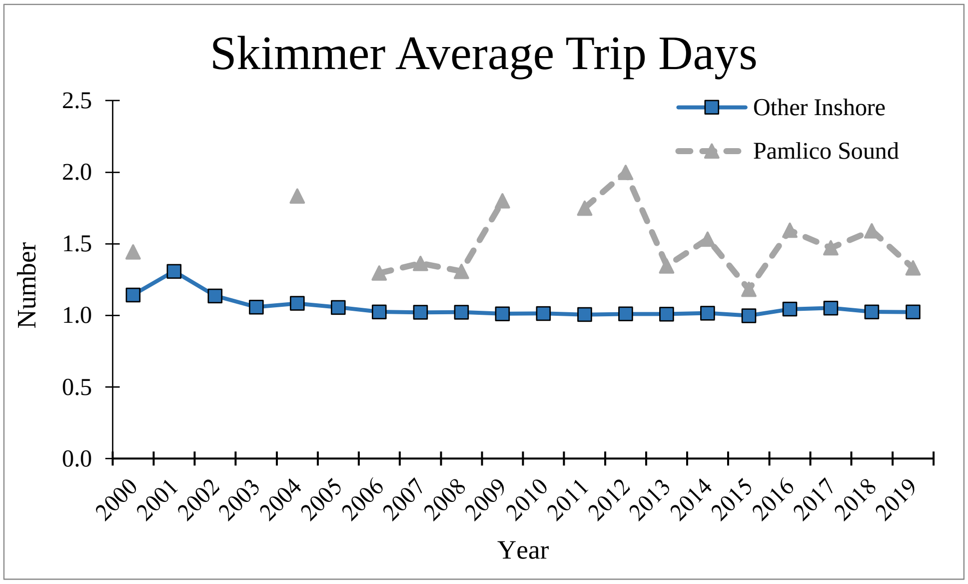


Figure 2.4.14. Average number of trip days by area for the North Carolina shrimp otter trawl fishery by year, 2000-2019.

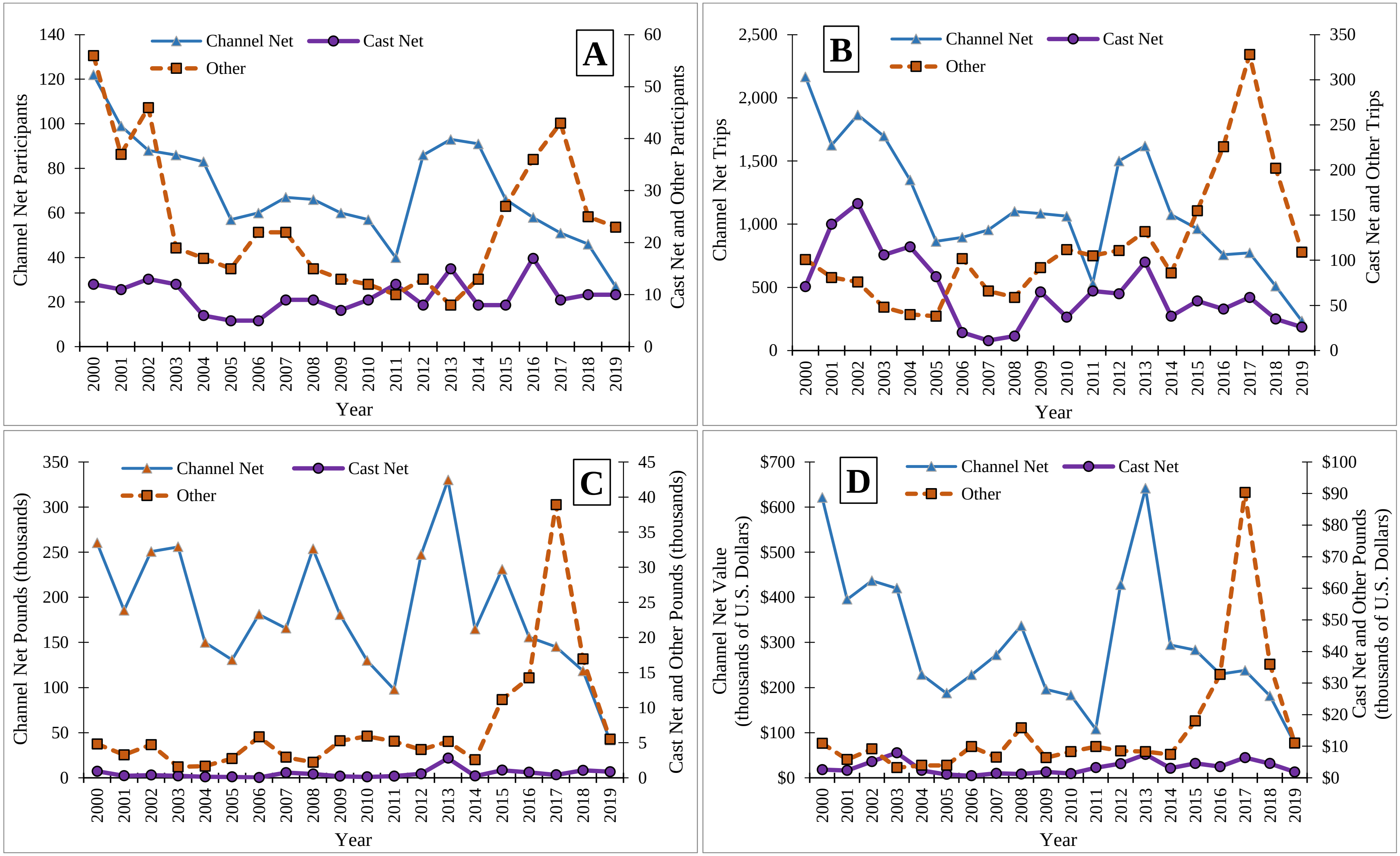


Figure 2.4.15. Commercial shrimp channel net, cast net, and other gear participants (A), trips (B), landings (C), and value (D), 2000-2019.

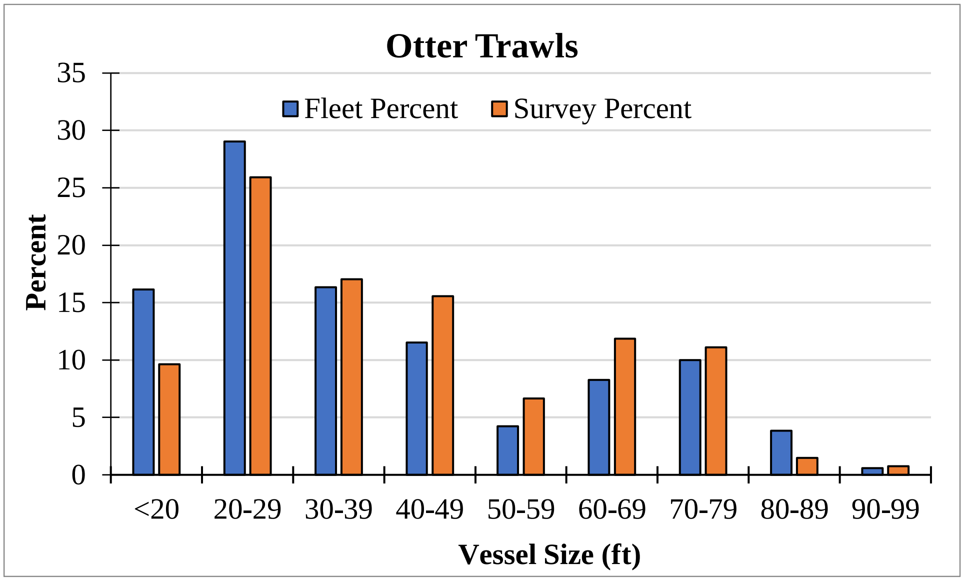


Figure 2.4.16. Commercial shrimp otter trawl fleet vessel size vs. surveyed portion of the fleet in the NCDMF BRD characterization survey.

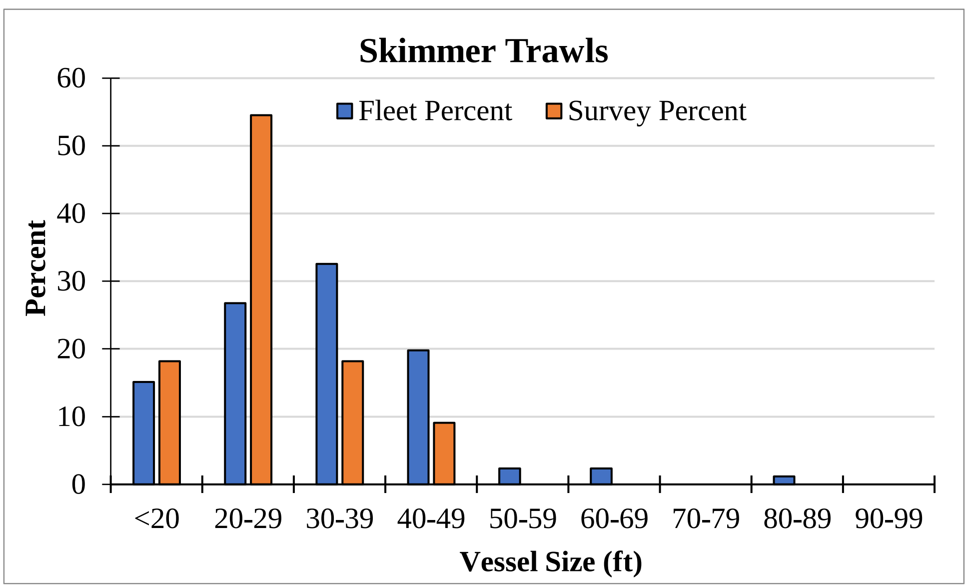


Figure 2.4.17. Commercial shrimp skimmer trawl fleet vessel size vs. surveyed portion of the fleet in the NCDMF BRD characterization survey.

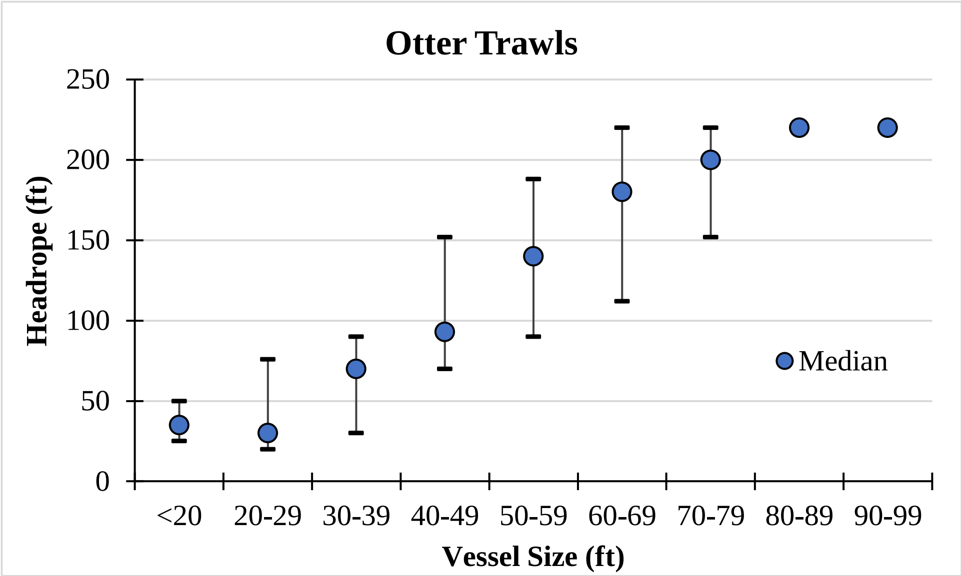


Figure 2.4.18. Commercial shrimp otter trawl median (blue dot), minimum (lower dash), and maximum (upper dash) total headrope per boat by vessel size bin from the NCDMF BRD characterization survey.

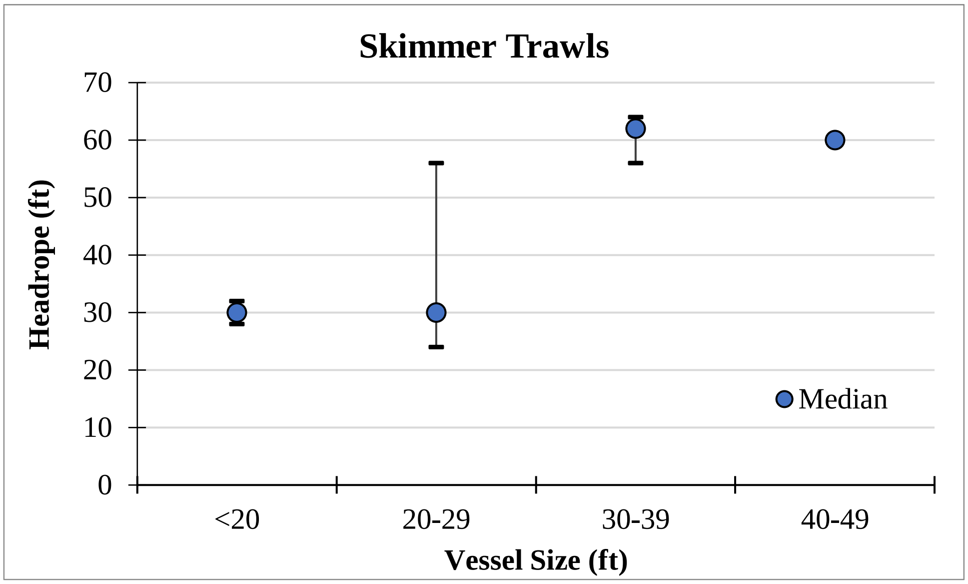


Figure 2.4.19. Commercial shrimp skimmer trawl median (blue dot), minimum (lower dash), and maximum (upper dash) total headrope per boat by vessel size bin from the NCDMF BRD characterization survey.

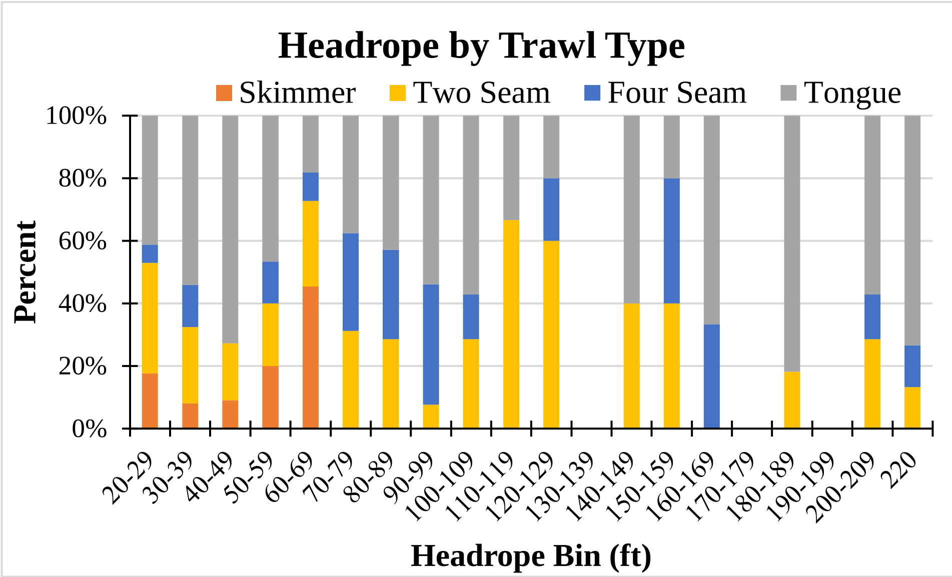


Figure 2.4.20. Proportion of net types by total headrope bin for vessels surveyed in the NCDMF BRD characterization survey.

APPENDIX 2.4.A. SHRIMP TRAWL BYCATCH EFFORT ANALYSES

Objective

The objective of these analyses was to determine what fishery and gear characteristics significantly affect CPUE of shrimp (brown, pink, and white) and finfish bycatch in the North Carolina shrimp trawl fishery.

Methods

Data sub-setting

The data included species sampled from individual tows (n = 1,567) obtained from commercial shrimp trawls in North Carolina waters within 3 areas (Pamlico Sound, offshore and inshore) from 2012 to 2017 (Table A1). The data was subset and aggregated by species groups as follows: "finfish" (all finfish), "key shrimp" (brown shrimp, pink shrimp, and white shrimp), "key bycatch" (blue crab, southern flounder, summer flounder, spot, croaker, and weakfish), and "key finfish" (southern flounder, summer flounder, spot, croaker, weakfish). Individual species were also subset as follows: white shrimp, brown shrimp, pink shrimp, blue crab, southern flounder, summer flounder, spot, croaker, weakfish.

Each dataset was analyzed in 5 scenarios with regards to area as follows: "3 areas" (all 3 areas included; 1, 567 individual tows), "2 areas" (Pamlico tows were combined with inshore and then offshore and inshore were both included; 1,567 individual tows), "Pamlico" (Pamlico only; 488 individual tows), "inshore" (inshore only not including Pamlico; 559 individual tows), and "offshore" (offshore only; 520 individual tows).

Potential predictors

Potential categorical predictors included year, day of the week, season, day or night tow, turtle excluder device (TED) position (position 0 = no TED, position 1 = top, position 2 = bottom), net type (net type 1 = two seamed, net type 2 = four seamed, net type 3 = tongue, net type 4 = skimmer), area (levels dependent on scenario as described previously), and management regime (Figure 2.4.A.1). Management regime was defined with two levels as prior and post June 2015 when regulations that were assumed to impact CPUE of catch and bycatch were implemented. Season was defined with three levels as follows: spring was from March 21st to June 21st, summer was from June 22nd to September 22nd, and fall was from September 23rd to December 21st. Day or night was defined with two levels as follows: in spring day was from 6:17 am to 8:04 pm, in summer day was from 6:25 am to 8:13 pm, and in fall day was from 6:41 am to 5:13 pm.

Potential numerical predictors included bycatch reduction device (BRD) placement from centerline (CL) (number of meshes), BRD placement from tailbag ties (TT) (number of meshes), wing mesh (bar mesh length in inches), tailbag mesh (bar mesh length in inches), tow speed (knots), tow duration (minutes), tow distance (nautical miles), TED bar spacing (inside edge to inside edge in inches), number of nets, total head-rope per boat, latitude, longitude, and interaction between latitude and longitude (Figure 2.4.A.2).

Spatial heterogeneity

Spatial components were an important consideration in determining which variables were the most significant predictors of CPUE. Spatial distribution and density maps were created for each species by area (Figures 2.4.A.3, A.4, and A.5).

Effort metrics

Several metrics were considered as appropriate measures for effort including tow duration (minutes) and distance towed (nautical miles). Distance towed was calculated as tow duration multiplied by tow speed (knots). The natural log of catch weight for each species group was plotted against tow duration and tow distance for visual comparison of the relationships between these metrics to catch weight (Figures 2.4.A.6, A.7, A.8, and A.9). Spearman's rank correlation coefficient (ρ) was calculated for each species group for the natural log of catch weight and tow duration (Table 2.4.A.2) and tow distance (Table 2.4.A.3). Correlations varied based on species group and tow distance had slightly higher correlations for most of the species groups; however, since correlations for both metrics were comparable, tow duration was selected as the unit of effort as this metric would be easier to use for enforcement purposes if future regulations were implemented to limit effort.

Modeling

To determine which variables were correlated with each other, variables were sequentially dropped from the variance inflation factor (VIF) analysis until all VIFs were below a value of 3 (Zuur et al. 2010). Total head-rope per boat and number of nets were found to be correlated (Tables 2.4.A.4, A.5, and A.6). Subsequently, number of nets was dropped as a potential predictor because it was determined that total head-rope per boat would be a more important variable to evaluate as a predictor.

The response variable modeled was the logarithm of CPUE (Y) using generalized least squares with a spatial correlation matrix to account for spatial, non-constant variance. The spatial correlation matrix was only included when it improved the model based on the difference in Akaike's information criterion (ΔAIC). Any model with latitude and/or longitude as predictor variables was not fitted with a spatial correlation matrix. Models were developed as:

$$Y \sim \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots + \varepsilon$$

where $\beta_{1,2,3,\ldots}$ were the coefficients for the potential predictor variables, $X_{1,2,3,\ldots}$ were the potential predictor variables, and ε was random error. Models that included a spatial correlation matrix were modeled as:

$$Y_l \sim \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots + \varepsilon_l$$

where *Y* at location *l* was modeled as previously with random error specific to location *l*.

A forward model selection process was implemented using a likelihood ratio test (LRT). Candidate models were developed by adding one predictor variable to the base model ($Y \sim 1$). The candidate models were compared to the base model with a LRT and the candidate model with the lowest p-value that was lower than the significance level (α) of 0.01 was adopted as the updated base model. This process was repeated until none of the candidate models were lower than the significance level.

To prevent the overfitting of models, a backward selection process was also incorporated where the resulting model from the forward selection was assigned as the base model and candidate models were developed by removing one predictor variable from the base model. The candidate models were compared to the base model using AIC. If the candidate model had a lower AIC than the base model, then the candidate was accepted as the updated base model. This process was repeated for each predictor variable until the candidate model AIC was no longer lower than the base model AIC.

Zero-inflation

Some species groups were zero-inflated (Table 2.4.A.7) and were modeled using two sub-models; a presence/absence model and the log(CPUE) model as described above. Species groups with the percentage of zeroes $\geq 60\%$ were considered zero-inflated and the presence/absence of the selected species group was modeled using a generalized linear model with a similar model structure as the log(CPUE) model except the response variable was binomially distributed and a spatial correlation matrix was not included.

Results

Plots were developed for each species group of log(CPUE) against each potential variable (Figures 2.4.A.10-A.22). Some variables indicated a relationship for predicting CPUE, for example, in Figure A14 the plot of CPUE against day or night indicates a possible significant difference between day and night for predicting CPUE however, the data was inadequate due to the high number of missing data points (93.2%). These results indicate a possible relationship for predicting CPUE based on the time of day and might be an avenue of further research.

3-area scenario

Results for the 3-area scenario indicate that for the log(CPUE) sub-models (Table 2.4.A.8), the predominant predictors for the various species groups were year (12 species groups), net type (11 species groups), area (8 species groups), and season (5 species groups). Management regime (3 species groups), day of the week (3 species groups), latitude (2 species groups), longitude (2 species groups), and the interaction between latitude and longitude (2 species groups) were each significant but not as frequently. The presence/absence sub-models (Table 2.4.A.9) indicate that of the five zero-inflated species groups with converged models; year (5 species groups), TED position (5 species groups), net type (5 species groups), and area (4 species groups) were the predominant predictors. Season (2 species groups), management regime (2 species groups), wing mesh (1 species group), tailbag mesh (1 species group), and BRD placement TT (1 species group) were each significant less frequently.
2-area scenario

Results for the 2-area scenario indicate that for the log(CPUE) sub-models (Table 2.4.A.8), the predominant predictors for the various species groups were year (12 species groups), net type (11 species groups), day of the week (4 species groups), season (5 species groups), and management regime (4 species groups). Area (3 species groups), latitude (1 species group), longitude (1 species group), and the interaction between latitude and longitude (1 species group) were each significant but not as frequently. The presence/absence sub-models (Table A9) indicate that of the five zero-inflated species groups with converged models; year (5 species groups), TED position (5 species groups), and net type (4 species groups) were the predominant predictor variables. Area (2 species groups), season (2 species groups), management regime (1 species group), wing mesh (2 species groups), tailbag mesh (1 species group), BRD placement TT (1 species group), latitude (1 species group), longitude (1 species group), and the interaction between latitude and longitude (1 species group) were each significant less frequently.

Inshore scenario

Results for the inshore scenario indicate that for the log(CPUE) sub-models (Table 2.4.A.8), the predominant predictors for the various species groups were year (9 species groups), net type (9 species groups), and season (5 species groups). Day of week, management regime, latitude, longitude, and the interaction between latitude and longitude were each significant for two species groups. The presence/absence sub-models (Table A9) indicate that of the five zero-inflated species groups with converged models; total head-rope per boat and TED bar spacing were significant for three species groups and were the predominant predictor variables. Year (2 species groups), TED position (2 species groups), day/ night (1 species group), season (2 species groups), management regime (1 species group), longitude (1 species group), and the interaction between season and longitude (1 species group) were each significant less frequently.

Offshore scenario

Results for the offshore scenario indicate that for the log(CPUE) sub-models (Table 2.4.A.8), the predominant predictors for the various species groups were year (8 species groups), net type (5 species groups), and season (7 species groups). Day of week was only significant for one species group and latitude, longitude, and the interaction between latitude and longitude were each significant for three species groups. The presence/absence sub-models (Table 2.4.A.9) indicate that of the four zero-inflated species groups with converged models; season (3 species groups) and BRD placement TT (2 species groups) were the two most frequent predictors. Year, management regime, wing mesh, BRD placement CL, TED bar spacing, latitude, longitude, and the interaction between latitude and longitude were each significant for only one species group.

Pamlico scenario

Results for the Pamlico scenario indicate that for the log(CPUE) sub-models (Table 2.4.A.8), the predominant predictors for the various species groups were year (10 species groups), TED position (5 species groups), net type (6 species groups), and season (8 species groups). Management regime (1 species group), latitude (4 species groups), longitude (4 species groups), and the interaction between latitude and longitude (4 species groups) were significant but not as frequently. The presence/absence sub-models (Table A9) indicate that of the four zero-inflated species groups with converged models; year, TED position, and TED bar spacing each were significant in 2 species groups and net type, season, management regime, wing mesh, total head-rope per boat and latitude were each significant for only one species group.

Discussion

The data used for these analyses were acquired opportunistically through onboard observations of commercial shrimp trawlers. Consequently, the data have some limitations as some areas have years and months with little or no data (Table 2.4.A.1). These results should be viewed as exploratory in nature and not conclusive.

There is some variation in the significant predictor variables dependent on the species or species group, scenario, and sub-model (Tables 2.4.A.8 and A.9). For example, for the log(CPUE) sub-models, TED position is almost exclusively important for the Pamlico area and the coefficients indicate that for brown shrimp and the key shrimp species group, position 2 (bottom) has the highest increase on CPUE and position 1 (top) has a higher increase on CPUE compared to position 0. However, for the log(CPUE) sub-model, there are consistent results for multiple species and species groups across scenarios. Specifically, of the 65 possible combinations of scenarios and species or species groups; year, net type, and season are significant for 80.0%, 66.2%, and 51.8% of the sub-models. Unfortunately, the presence/absence sub-models provide less clearly distinct generalizations yet, there is still valuable species-specific information.

For example, spot and weakfish were encountered in shrimp trawls more frequently than other key bycatch species, present in 93.3% and 54.1%, respectively, of all trawl samples and present 99.2% and 73%, respectively, in trawl samples from Pamlico Sound where the majority of estuarine shrimp harvest and effort occurs (Table 2.4.A.7). For spot, net type was a significant factor in the 3-area, 2-area, and inshore models with tongue style nets having more bycatch than two-seam and four-seam nets. Similarly, net type was also a significant factor for weakfish in the 3-area, 2-area, inshore, offshore, and Pamlico models with tongue nets having more bycatch. This suggests net type may be important to consider when discussing methods to reduce bycatch for these species. Season was also consistently a significant factor for weakfish in all the models, with summer having higher rates of bycatch in the 3-area, 2-area, inshore, and offshore models, and the fall having higher rates of bycatch in Pamlico model. This suggests for weakfish that season should be considered when discussing methods to reduce bycatch and that one approach may not work for all areas.

Although results of these analyses are inconclusive, this work does provide some direction for future research efforts. The significant data gaps also highlight the need for more consistent monitoring of discards in the shrimp trawl fishery through a dedicated onboard observer program and/or directed experimental research. This will allow more constructive and focused efforts to be made to reduce bycatch in the shrimp trawl fishery.

Literature Cited

Zuur, A.F., Ieno, E.N., Elphick, C.S. 2010. A protocol for data exploration to avoid common statistical problems: Data exploration. Methods in Ecology and Evolution 1, 3–14. https://doi.org/10.1111/j.2041-210X.2009.00001.x

Tables

Table 2.4.A.1. Number of individual tows sampled by area, year, and month, 2012-2017.

		Month									
Area	Year	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
All areas (1,567 tows)	2012	0	0	0	0	0	61	55	61	21	23
	2013	0	6	46	45	54	1	33	30	24	4
	2014	0	0	11	88	128	71	48	50	0	0
	2015	0	0	14	89	50	80	61	85	11	0
	2016	4	20	19	33	41	37	23	27	13	0
	2017	0	10	10	11	0	32	30	7	0	0
	Totals	4	36	100	266	273	282	250	260	69	27
Inshore (559 tows)	2012	0	0	0	0	0	22	21	17	0	6
	2013	0	6	23	4	0	0	0	3	0	0
	2014	0	0	0	5	0	7	5	16	0	0
	2015	0	0	7	46	12	10	61	85	11	0
	2016	0	20	3	17	30	23	20	6	0	0
	2017	0	10	10	3	0	20	28	2	0	0
	Totals	0	36	43	75	42	82	135	129	11	6
Offshore (520 tows)	2012	0	0	0	0	0	14	23	20	21	17
	2013	0	0	23	26	17	1	15	6	15	4
	2014	0	0	11	68	24	8	15	34	0	0
	2015	0	0	4	25	13	32	0	0	0	0
	2016	4	0	16	16	4	0	3	21	13	0
	2017	0	0	0	0	0	0	2	5	0	0
	Totals	4	0	54	135	58	55	58	86	49	21
Pamlico (488 tows)	2012	0	0	0	0	0	25	11	24	0	0
	2013	0	0	0	15	37	0	18	21	9	0
	2014	0	0	0	15	104	56	28	0	0	0
	2015	0	0	3	18	25	38	0	0	0	0
	2016	0	0	0	0	7	14	0	0	0	0
	2017	0	0	0	8	0	12	0	0	0	0
	Totals	0	0	3	56	173	145	57	45	9	0

Table 2.4.A.2. Correlation results for Ln(catch weight) vs. tow duration.

Species	Spearman ρ
Brown	0.59
Croaker	0.55
Spot	0.53
Key bycatch	0.51
Key shrimp	0.51
Key finfish	0.5
Finfish	0.49
Crab	0.48
Weakfish	0.4
Southern	0.36
Summer	0.36
Pink	0.36
White	0.18

Table 2.4.A.3. Correlation results for Ln(catch weight) vs. distance towed.

Species	Spearman ρ
Brown	0.63
Croaker	0.61
Spot	0.57
Key finfish	0.55
Key bycatch	0.55
Finfish	0.54
Key shrimp	0.53
Pink	0.48
Crab	0.46
Weakfish	0.44
Summer	0.4
Southern	0.38
White	0.14

Table 2.4.A.4. Correlation variance inflation factors for potential model variables with headrope per boat and number of nets included. Values under 3 are acceptable for modeling.

Variable	Variance Inflation Factors
Wing mesh	1.57
Tailbag mesh	1.40
Tow speed	2.60
BRD placement TT	1.36
BRD placement CL	1.30
TED bar spacing	1.92
Number of nets	9.48
Total head-rope per boat	9.92

Table 2.4.A.5. Correlation variance inflation factors for potential model variables without headrope per boat. Values under 3 are acceptable for modeling.

Variable	Variance Inflation Factors
Wing mesh	1.47
Tailbag mesh	1.35
Tow speed	2.56
BRD placement TT	1.35
BRD placement CL	1.10
TED bar spacing	1.76
Number of nets	2.73

Table 2.4.A.6. Correlation variance inflation factors for potential model variables without numb of nets. Values under 3 are acceptable for modeling.

Variable	Variance Inflation Factors
Wing mesh	1.56
Tailbag mesh	1.39
Tow speed	2.52
BRD placement TT	1.33
BRD placement CL	1.13
TED bar spacing	1.90
Total head-rope per boat	2.86

Table 2.4.A.7. Percentage of tows with zero catches of species group for each area subset.

Species group	All areas	Inshore	Offshore	Pamlico
Finfish	1.8	3.0	1.9	0.2
Key shrimp	1.7	2.7	1.9	0.2
Key bycatch	1.9	3.0	2.1	0.2
Key finfish	1.9	3.2	2.1	0.2
Blue crab	62.5	57.4	89.6	39.5
Spot	6.7	12.9	5.6	0.8
Croaker	47.5	22.4	61.2	61.9
Southern flounder	78.0	87.3	82.3	62.7
Summer flounder	73.1	81.0	71.7	65.4
Weakfish	44.9	63.0	42.1	27.0
White shrimp	74.6	43.1	86.9	97.5
Brown shrimp	38.7	69.1	33.3	9.6
Pink shrimp	88.4	90.5	81.7	93.0

Table 2.4.A.8. Log(CPUE) model predictor variables for each analysis.

Species/ Group Variable	**FF**	**KF**	**KB**	**KS**	**Bc**	**Sp**	**Cr**	**So**	**Su**	**Wf**	**Ws**	**Bs**	**Ps**
Year	32POI	32POI	32POI	32POI	32I	32POI	32POI	32PO	32P	32POI	32PI	32P	
TED Pos.		P		P		P	P					P	32
Net Type	32POI	32OI	32POI	32I	32PI	32OI	32I		32P	32POI		32PI	32P
Area	32	3	3	32	3	3				3		32	
Day of Week		2		32OI							32I	32	
Day/ Night													
Season	32PO	P	P	32PI	32P	P	POI	32POI	O	32POI		OI	32O
Manage. Regime			2	32I	P	3	32			2			I
Wing Mesh													
Tailbag Mesh													
Tow Speed													
BRD Place TT													
BRD Place CL													
TED bar spacing													
Headrope / Boat													
Number of Nets													
Latitude					3			I	32PO	P		POI	PO
Longitude					3			I	32PO	P		POI	PO
Lat * Lon					3			I	32PO	P		POI	PO

Abbreviations are as follows:
FF: Finfish, **KF**: Key finfish, **KB**: Key bycatch, **KS**: Key shrimp, **Bc**: Blue crab, **Sp**: Spot, **Cr**: Croaker, **So**: Southern flounder, **Su**: Summer flounder, **Wf**: Weakfish, **Ws**: White shrimp, **Bs**: Brown shrimp, **Ps**: Pink shrimp.

Area symbol coding as follows:
3: 3 areas (inshore, offshore, & Pamlico), **2**: 2 areas (inshore & offshore), **P**: Pamlico, **O**: offshore, **I**: inshore.

Table 2.4.A.9. Presence/absence model predictor variables for data sets that were zero-inflated.

Species/ Group Variable	**FF**	**KF**	**KB**	**KS**	**Bc**	**Sp**	**Cr**	**So**	**Su**	**Wf**	**Ws**	**Bs**	**Ps**
Year					32		P	32POI	32I		32		32
TED Pos.					32		P	32	32PI		32	I	32
Net Type					32			32	3		32		32P
Area					32			32	3		3		
Day of Week													
Day or Night										I			
Season								OI	O		32O	I	32P
Season * Lon								I					
Manage. Regime					32						2O		3PI
Wing Mesh							P		3O				
Tailbag Mesh									3				
Tow Speed													
BRD Place TT								O			O		32
BRD Place CL											O		
TED bar spacing							P	I	POI			I	
Headrope / Boat									2PI			I	I
Number of Nets													
Latitude							P		O		2		
Longitude								I	O		2		
Lat * Lon									O		2		

Abbreviations are as follows:
FF: Finfish, **KF**: Key finfish, **KB**: Key bycatch, **KS**: Key shrimp, **Bc**: Blue crab, **Sp**: Spot, **Cr**: Croaker, **So**: Southern flounder, **Su**: Summer flounder, **Wf**: Weakfish, **Ws**: White shrimp, **Bs**: Brown shrimp, **Ps**: Pink shrimp.

Area symbol coding as follows:
3: 3 areas (inshore, offshore, & Pamlico), **2**: 2 areas (inshore & offshore), **P**: Pamlico, **O**: offshore, **I**: inshore.

Figures

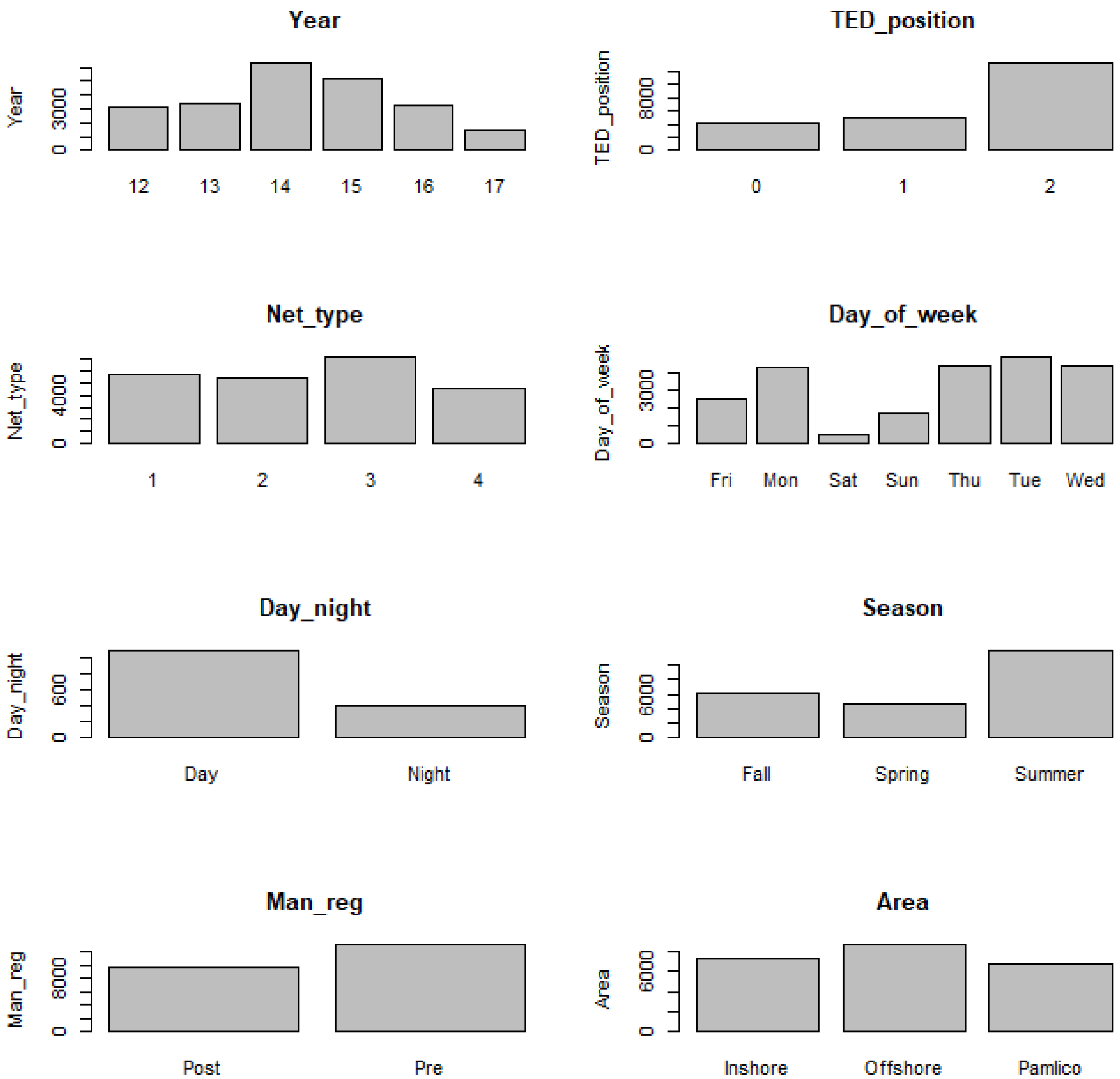


Figure 2.4.A.1. Histograms of potential categorical variables. "Man_reg" refers to management regime.

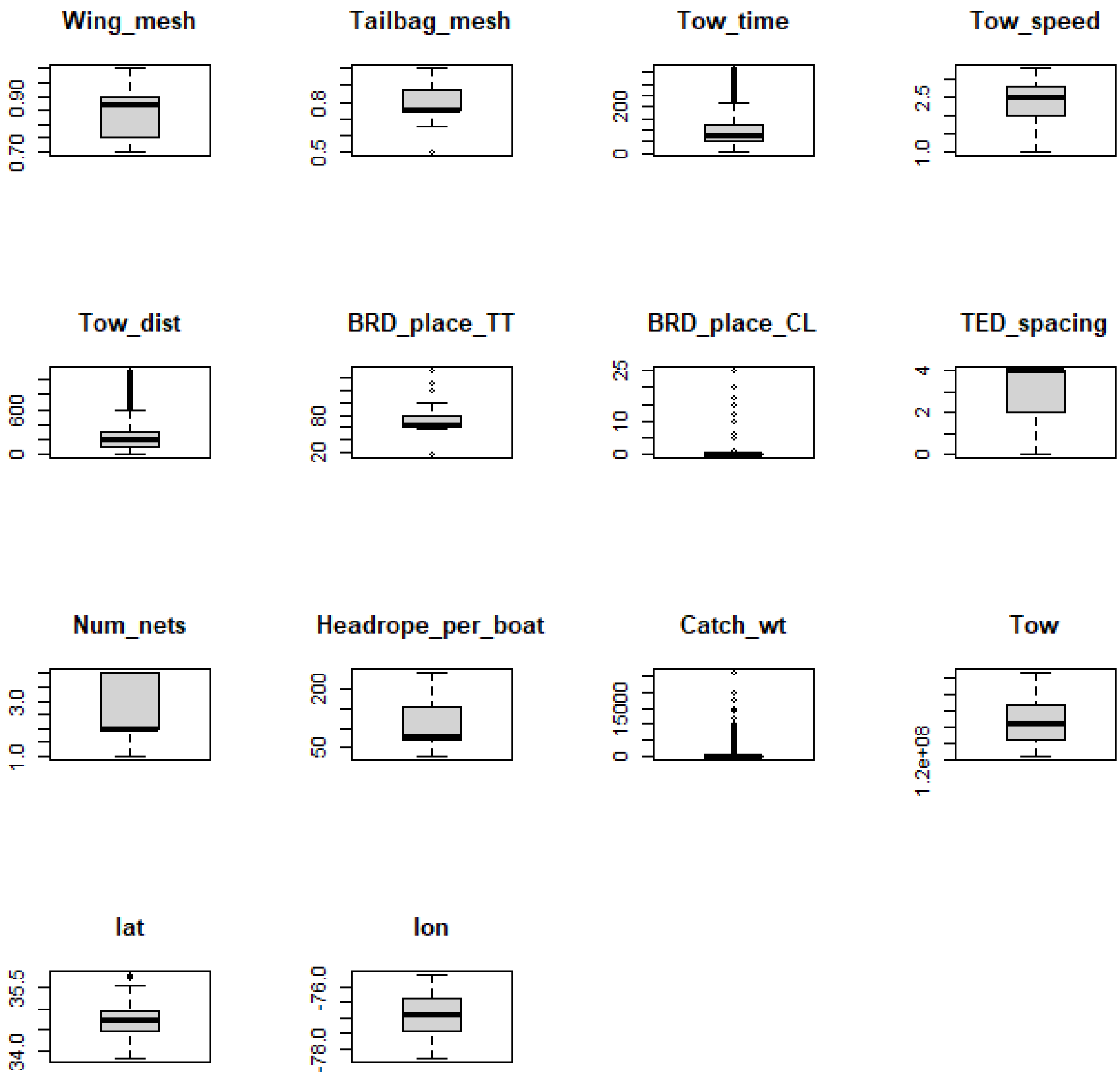


Figure 2.4.A.2. Boxplots of potential numerical variables. “lat”, “lon”, and “Num_nets” refer to latitude, longitude, and number of nets, respectively.

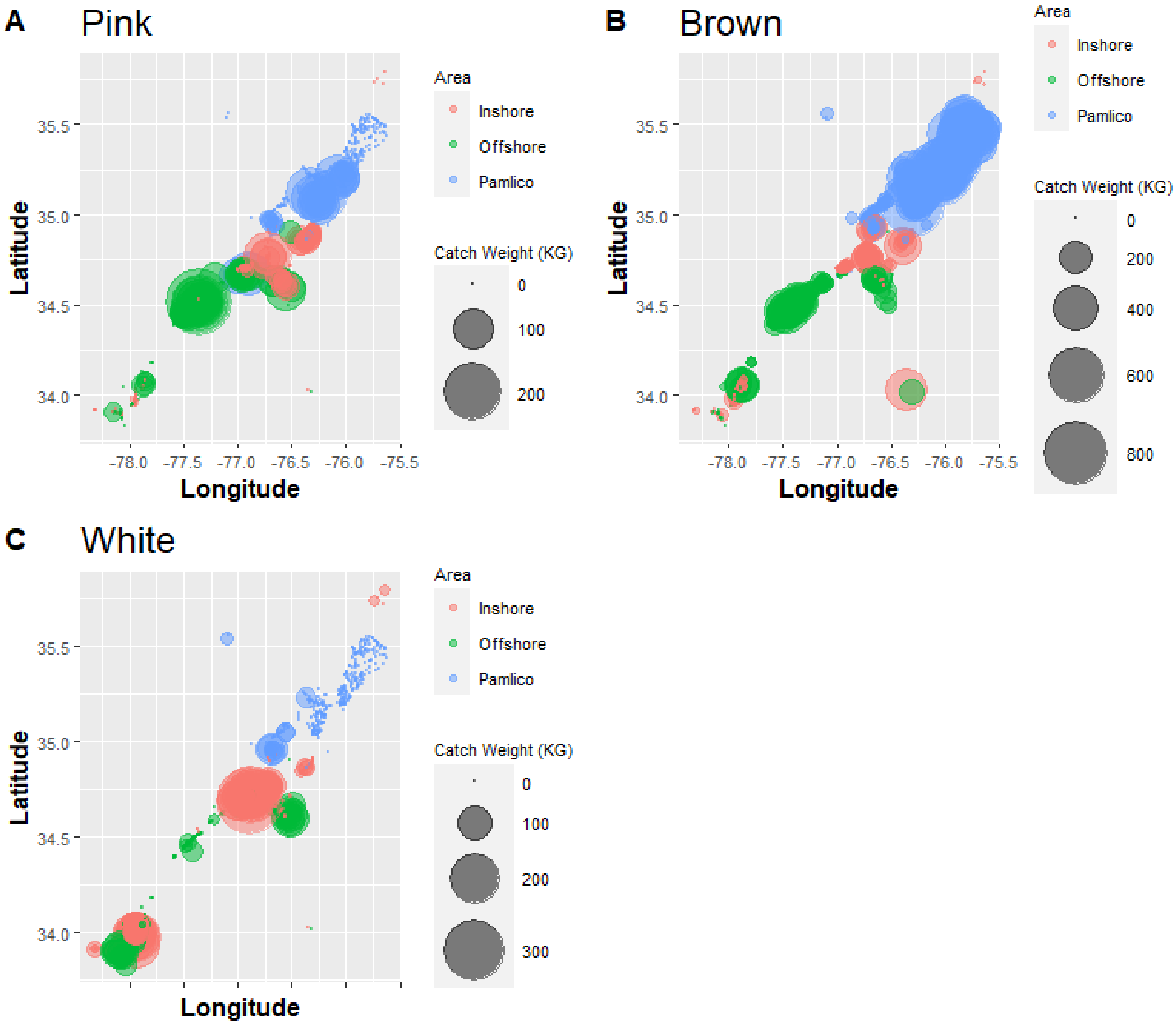


Figure 2.4.A.3. Spatial distribution and density of catch for pink shrimp (a), brown shrimp (b), and white shrimp (c).

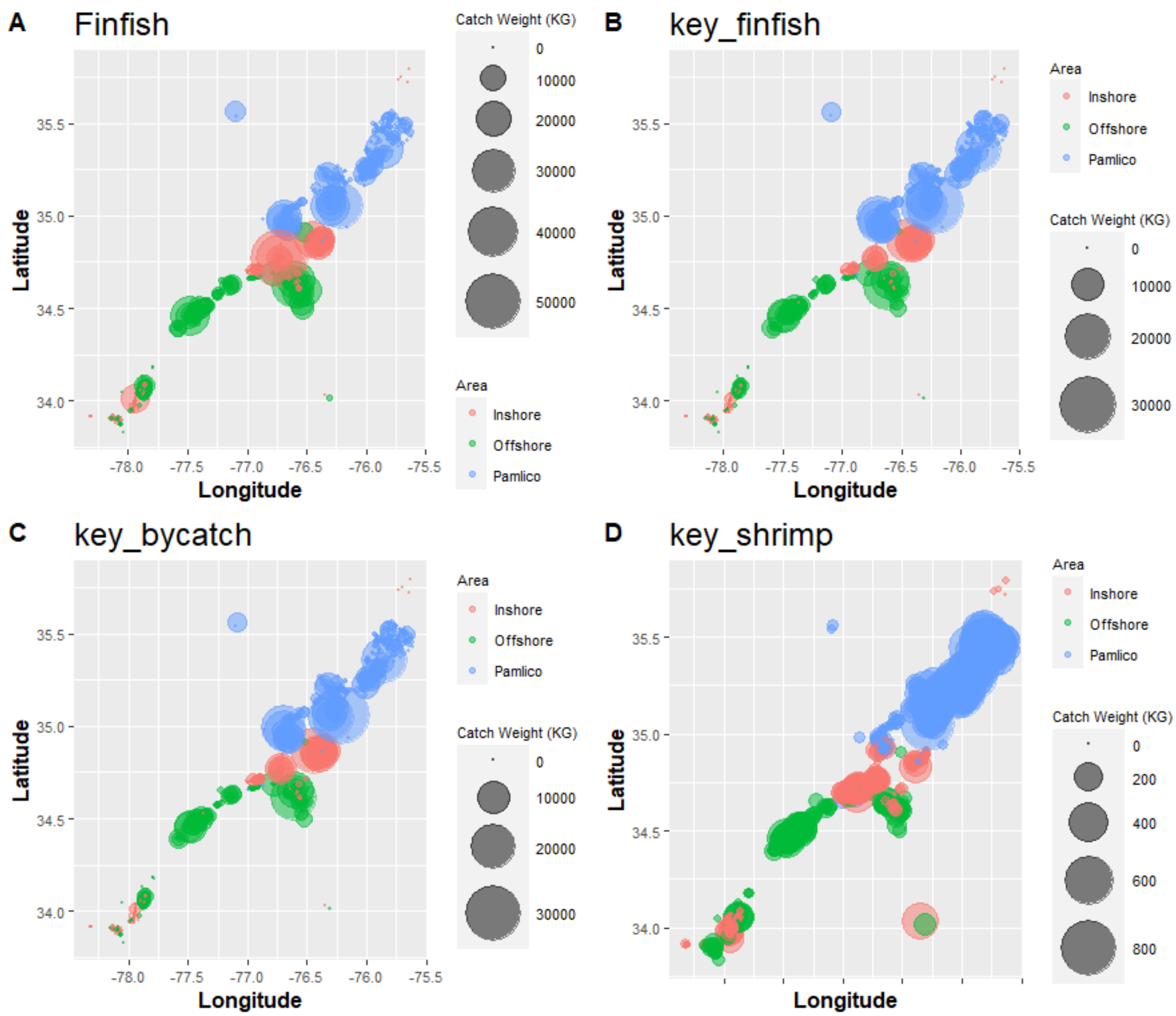


Figure 2.4.A.4. Spatial distribution and density of catch for finfish (a), key finfish (b), key bycatch (c), and key shrimp (d).

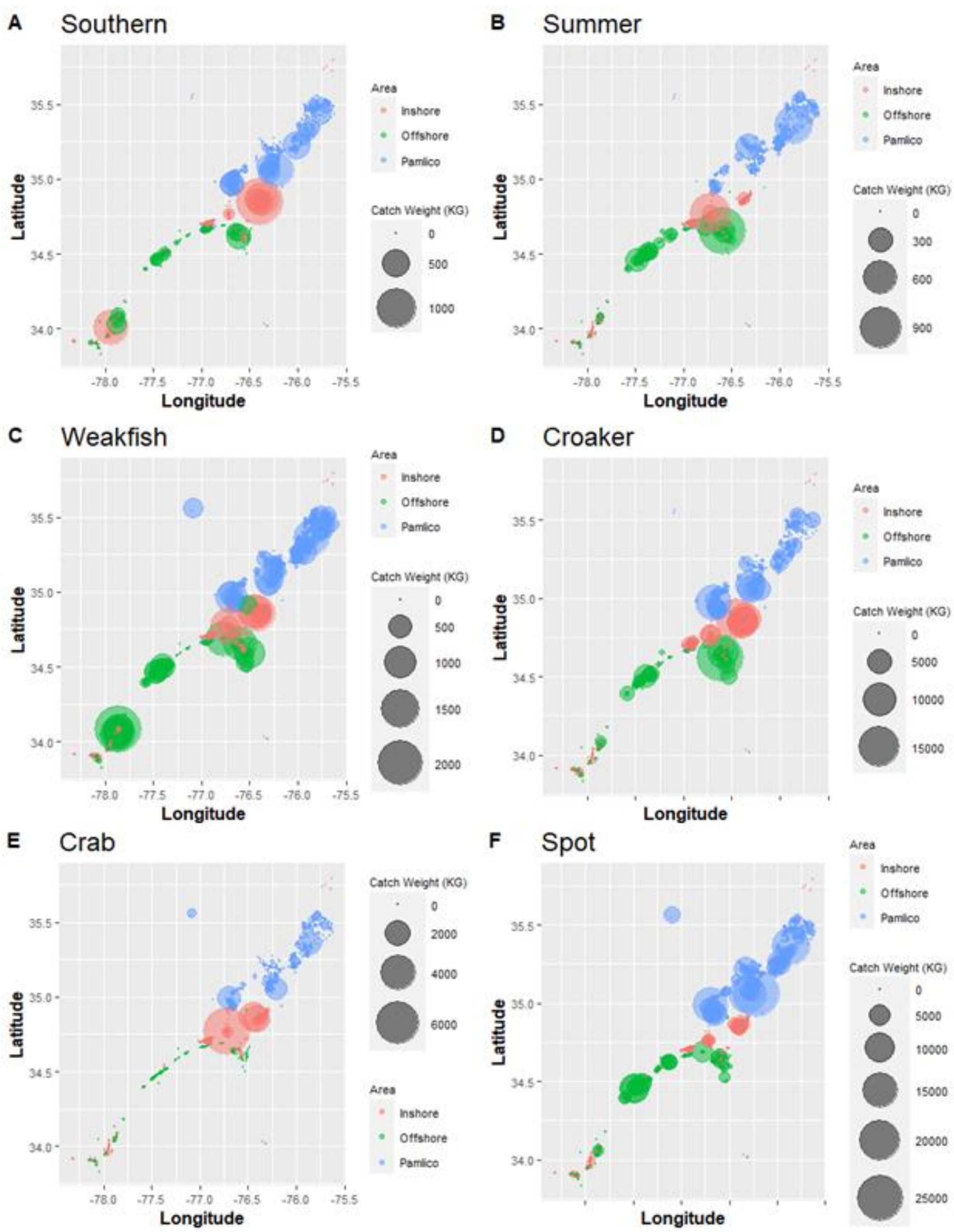


Figure 2.4.A.5. Spatial distribution and density of catch for southern flounder (a), summer flounder (b), weakfish (c), croaker (d), blue crab (e), and spot (f).

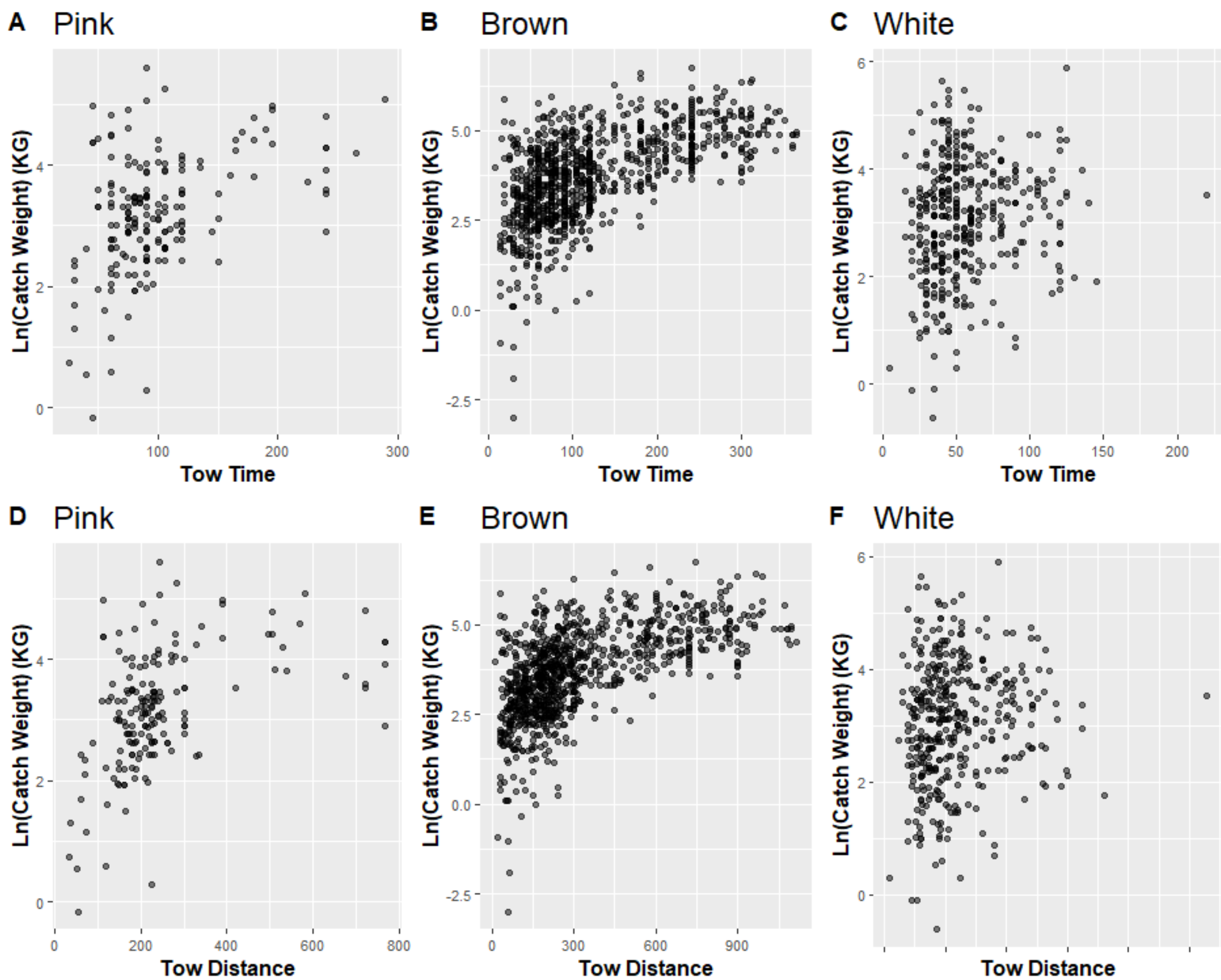


Figure 2.4.A.6. The natural log of catch weight (KG) was plotted against tow duration (tow time) for pink shrimp (a), brown shrimp (b), and white shrimp (c). The natural log of catch weight (KG) was plotted against distance towed for pink shrimp (d), brown shrimp (e), and white shrimp (f).

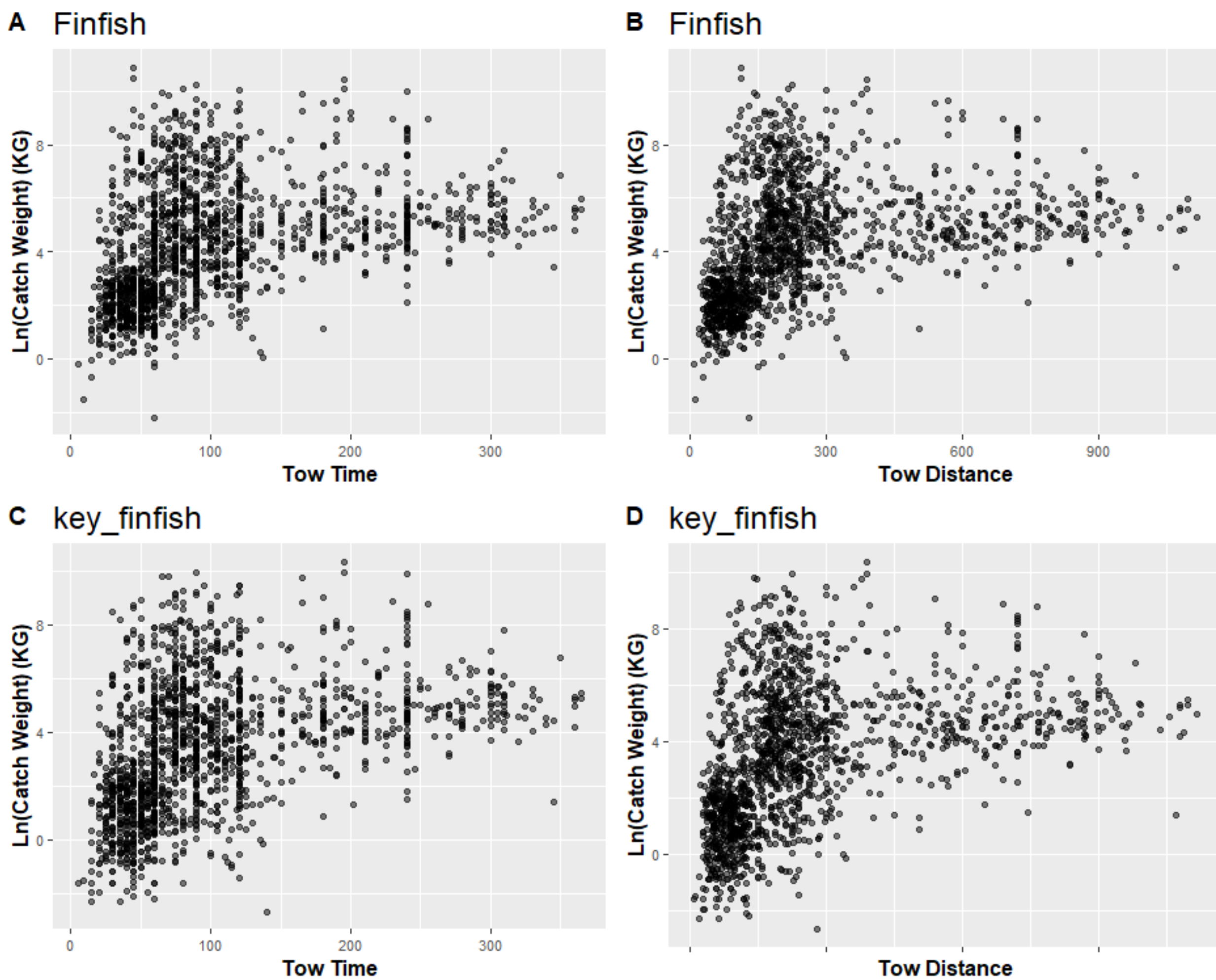


Figure 2.4.A.7. The natural log of catch weight (KG) was plotted against tow duration (tow time) for finfish (a) and key finfish (c). The natural log of catch weight (KG) was plotted against distance towed for finfish (b) and key finfish (d).

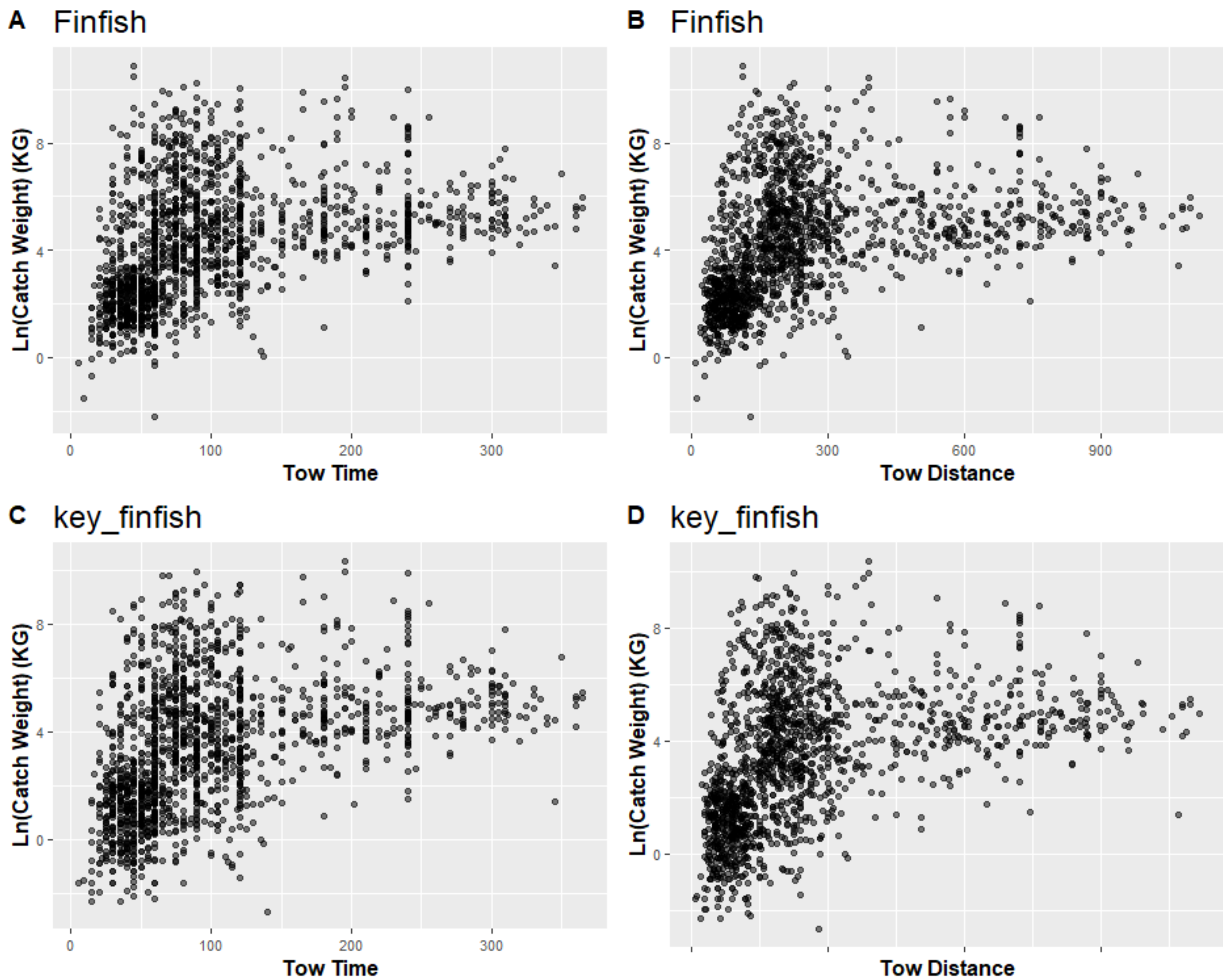


Figure 2.4.A.8. The natural log of catch weight (KG) was plotted against tow duration (tow time) for finfish (a) and key finfish (c). The natural log of catch weight (KG) was plotted against distance towed for finfish (b) and key finfish (d).

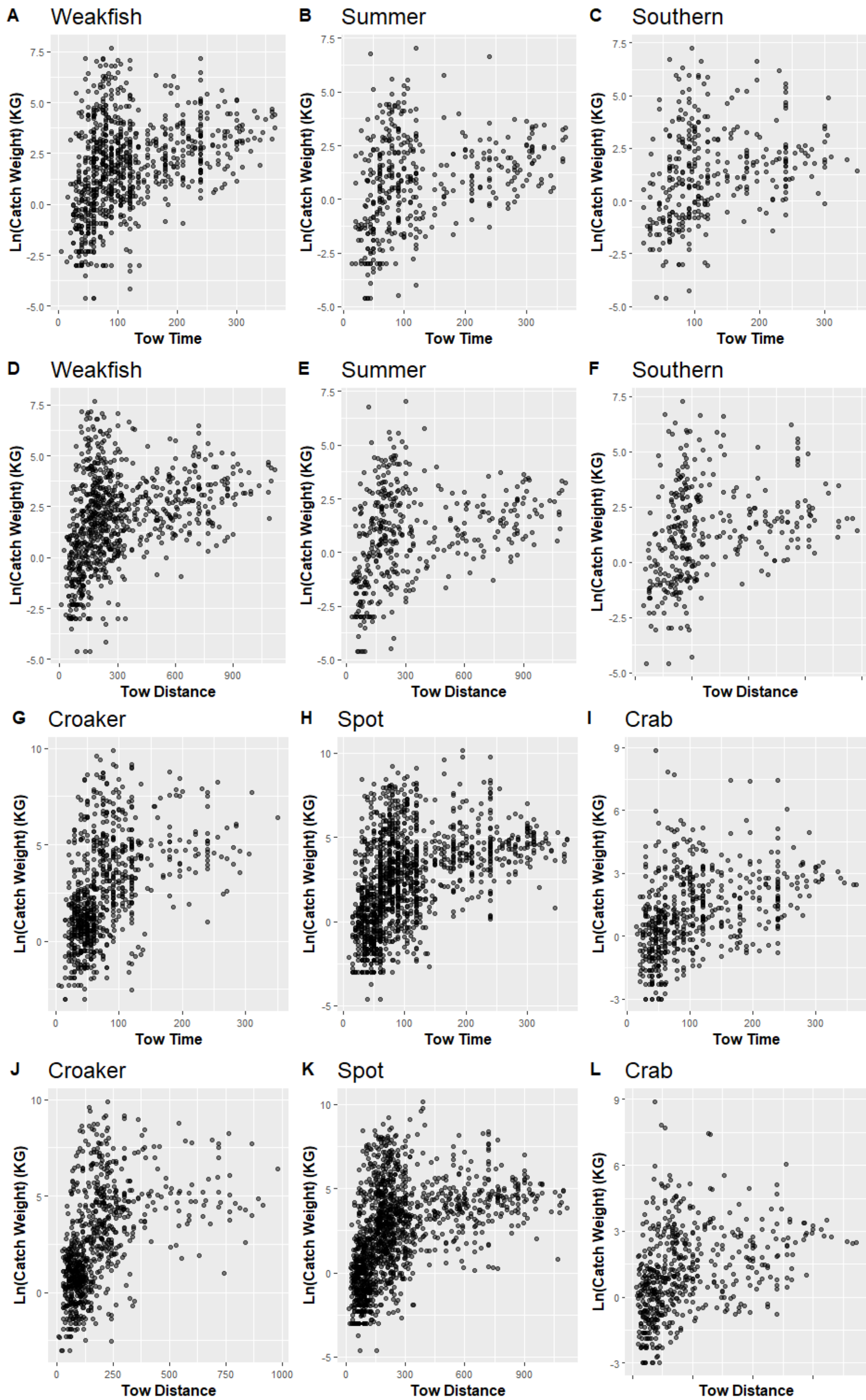


Figure 2.4.A.9. The natural log of catch weight (KG) was plotted against tow duration (tow time) for weakfish (a), summer flounder (b), southern flounder (c), croaker (g), spot (h), and blue crab (i). The natural log of catch weight (KG) was plotted against distance towed for weakfish (d), summer flounder(e), southern flounder (f), croaker (j), spot (k), and blue crab (l).

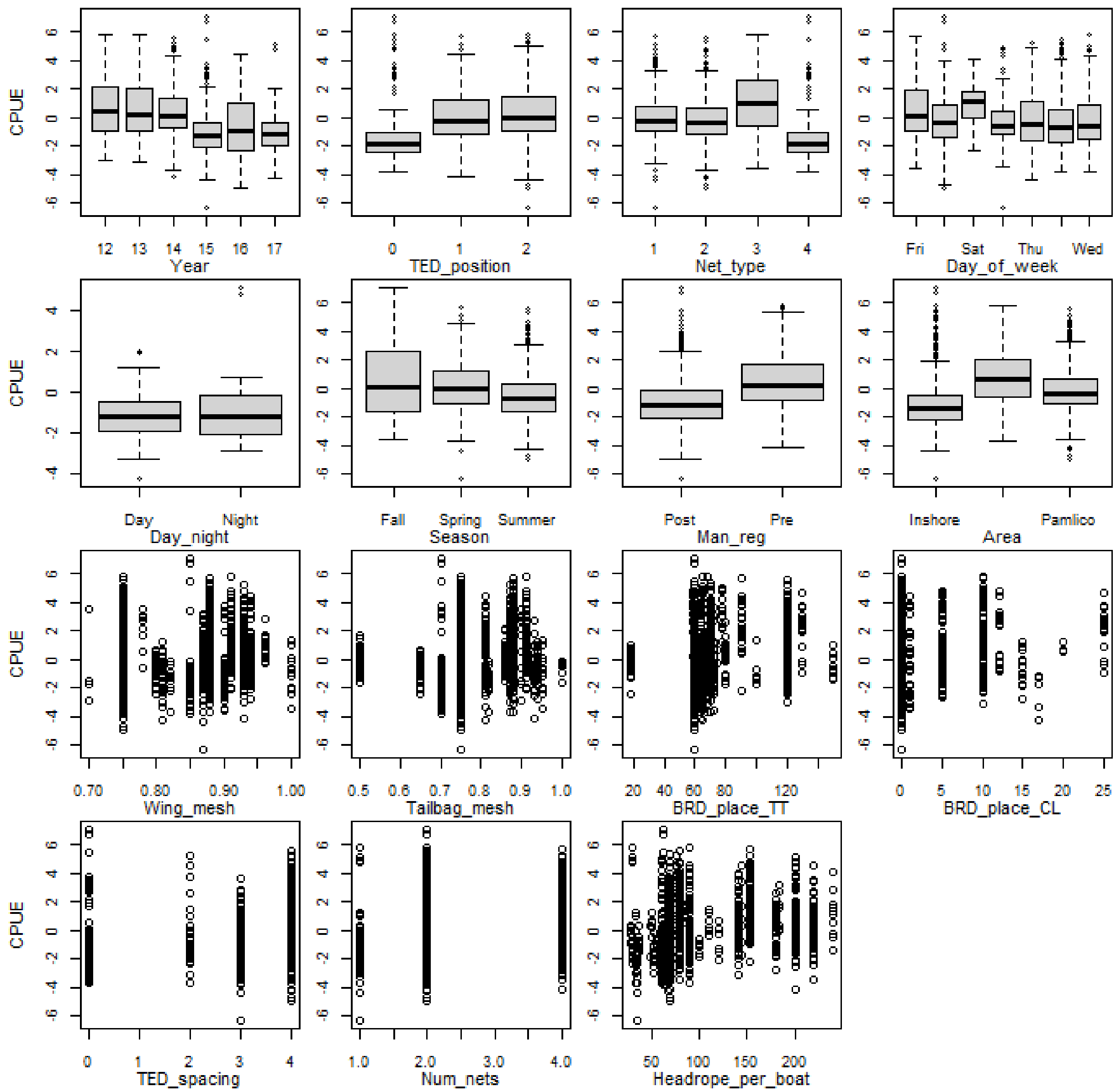


Figure 2.4.A.10. Plots of log(CPUE) against each potential predictor variable for finfish.

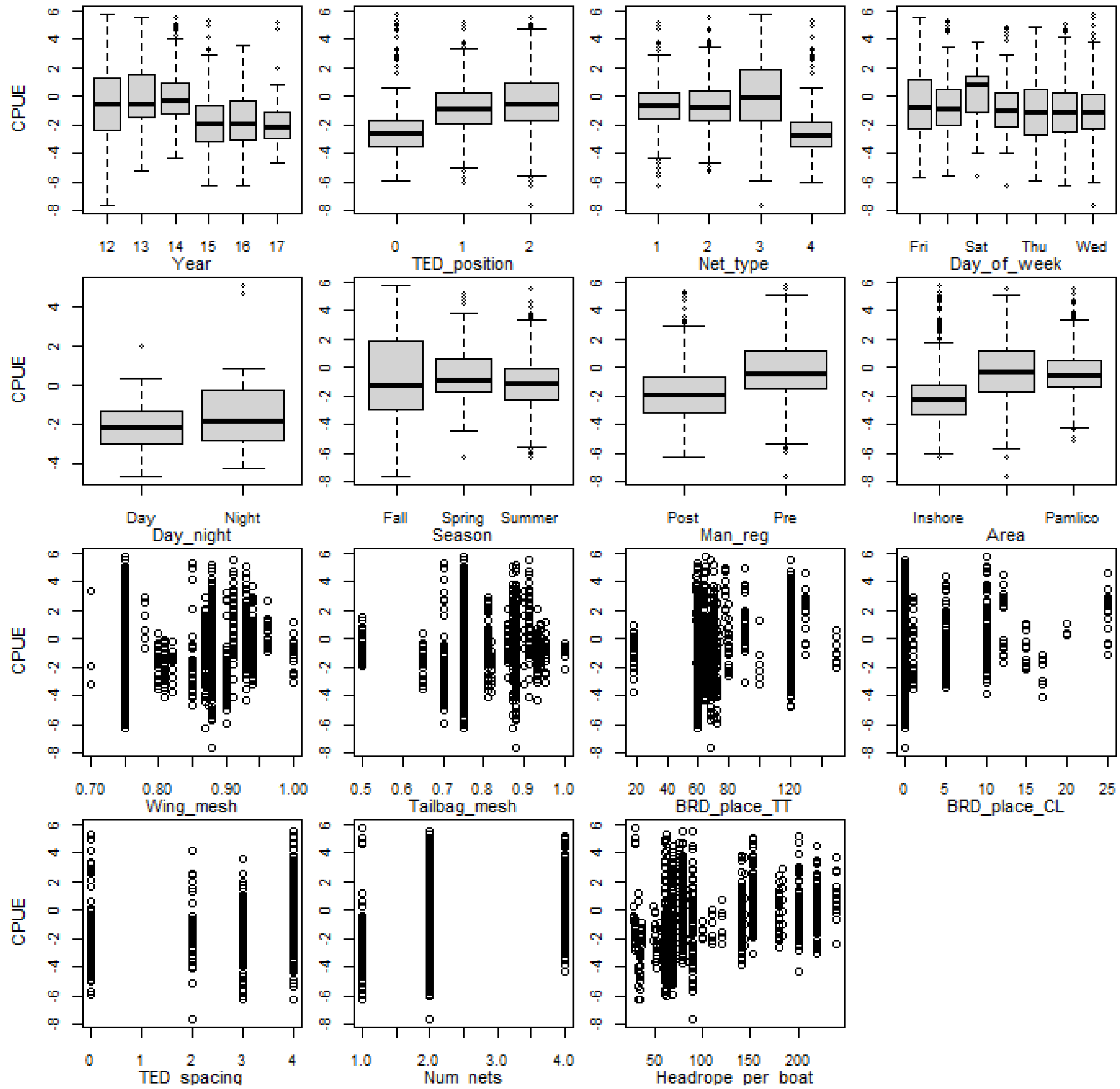


Figure 2.4.A.11. Plots of log(CPUE) against each potential predictor variable for key bycatch (blue crab, southern flounder, summer flounder, spot, croaker, and weakfish).

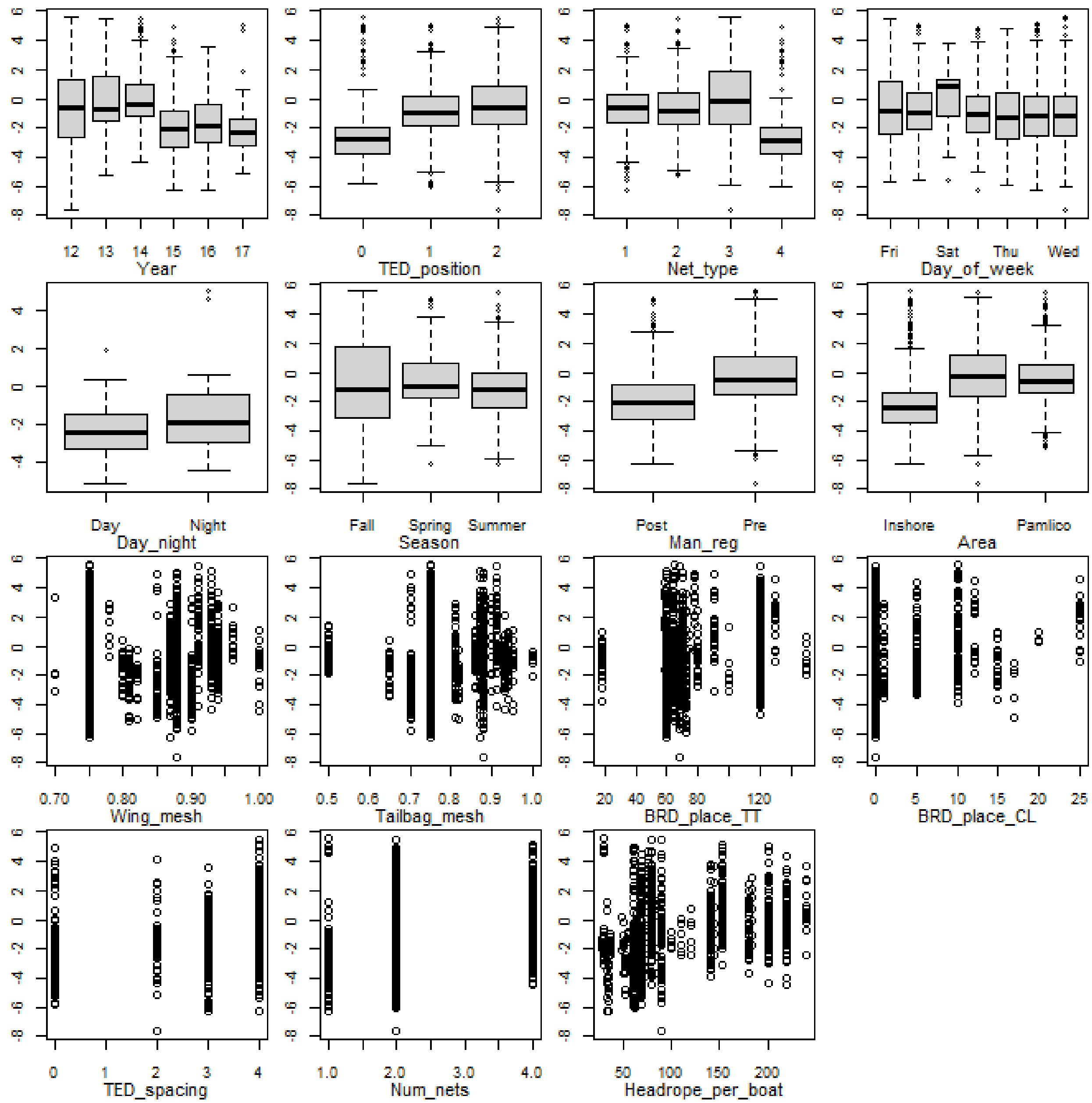


Figure 2.4.A.11. Plots of log(CPUE) against each potential predictor variable for key finfish (southern flounder, summer flounder, spot, croaker, and weakfish).

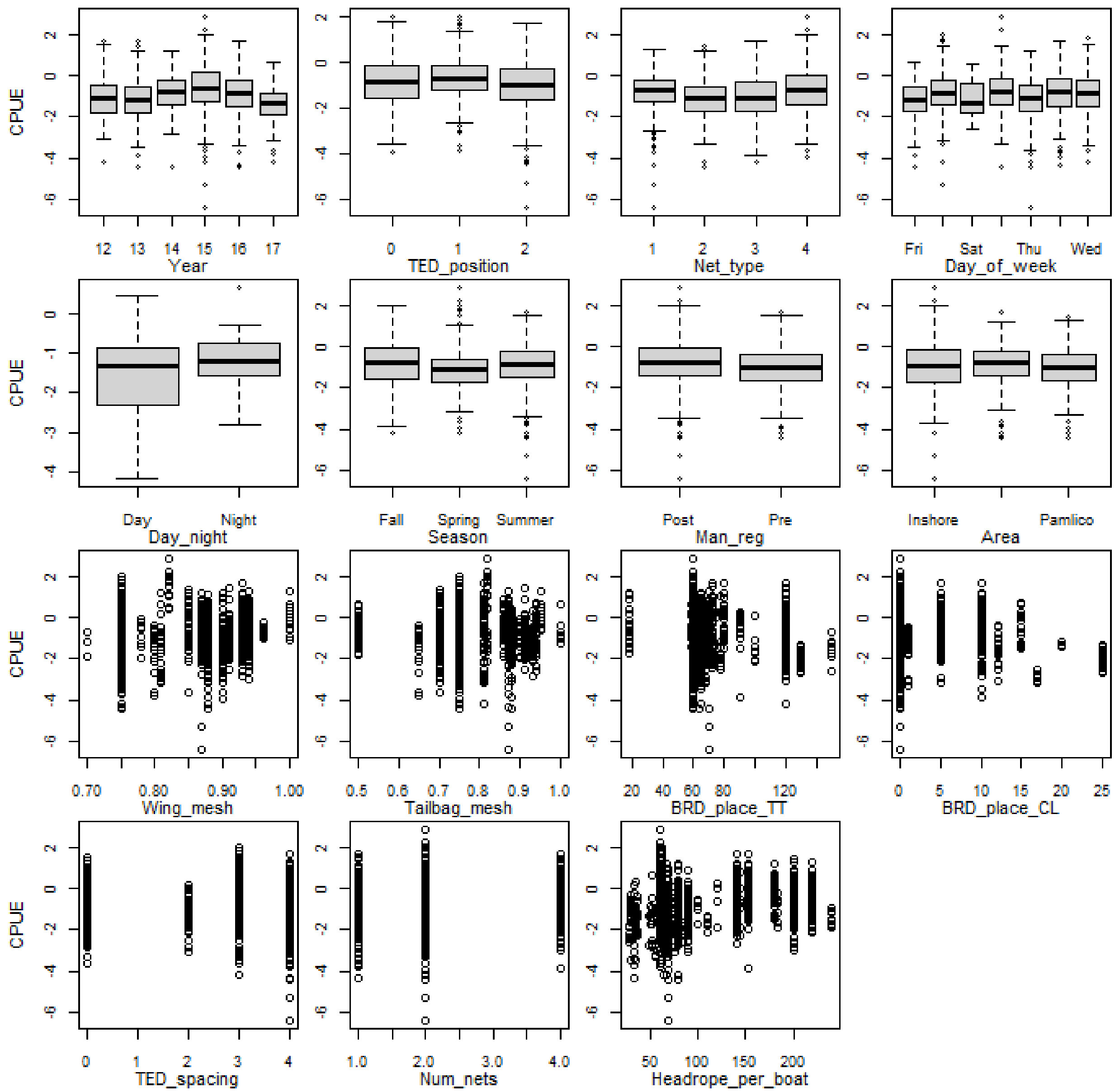


Figure 2.4.A.13. Plots of log(CPUE) against each potential predictor variable for key shrimp (brown, white, and pink).

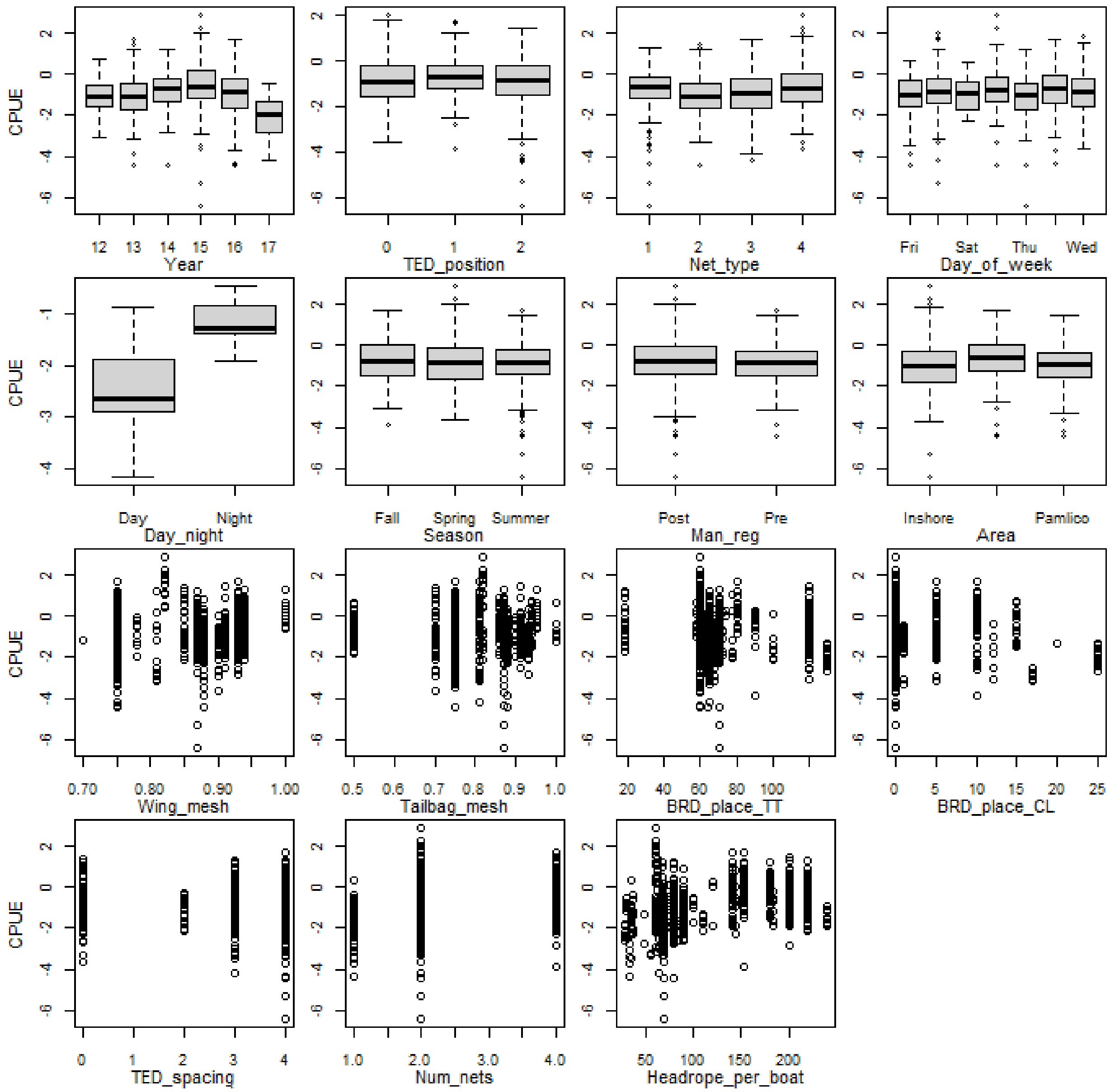


Figure 2.4.A.14. Plots of log(CPUE) against each potential predictor variable for brown shrimp.

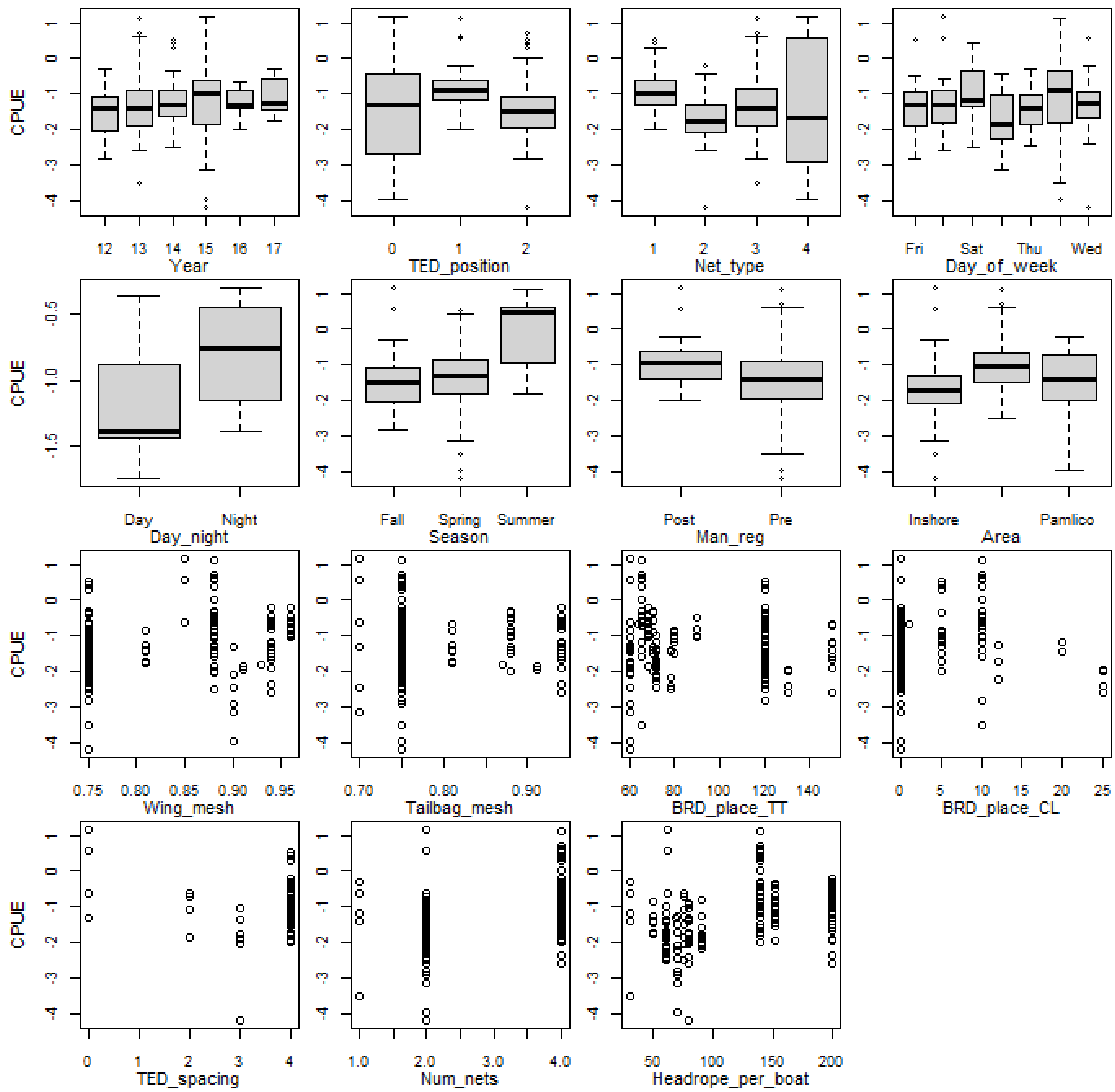


Figure 2.4.A.15. Plots of log(CPUE) against each potential predictor variable for pink shrimp.

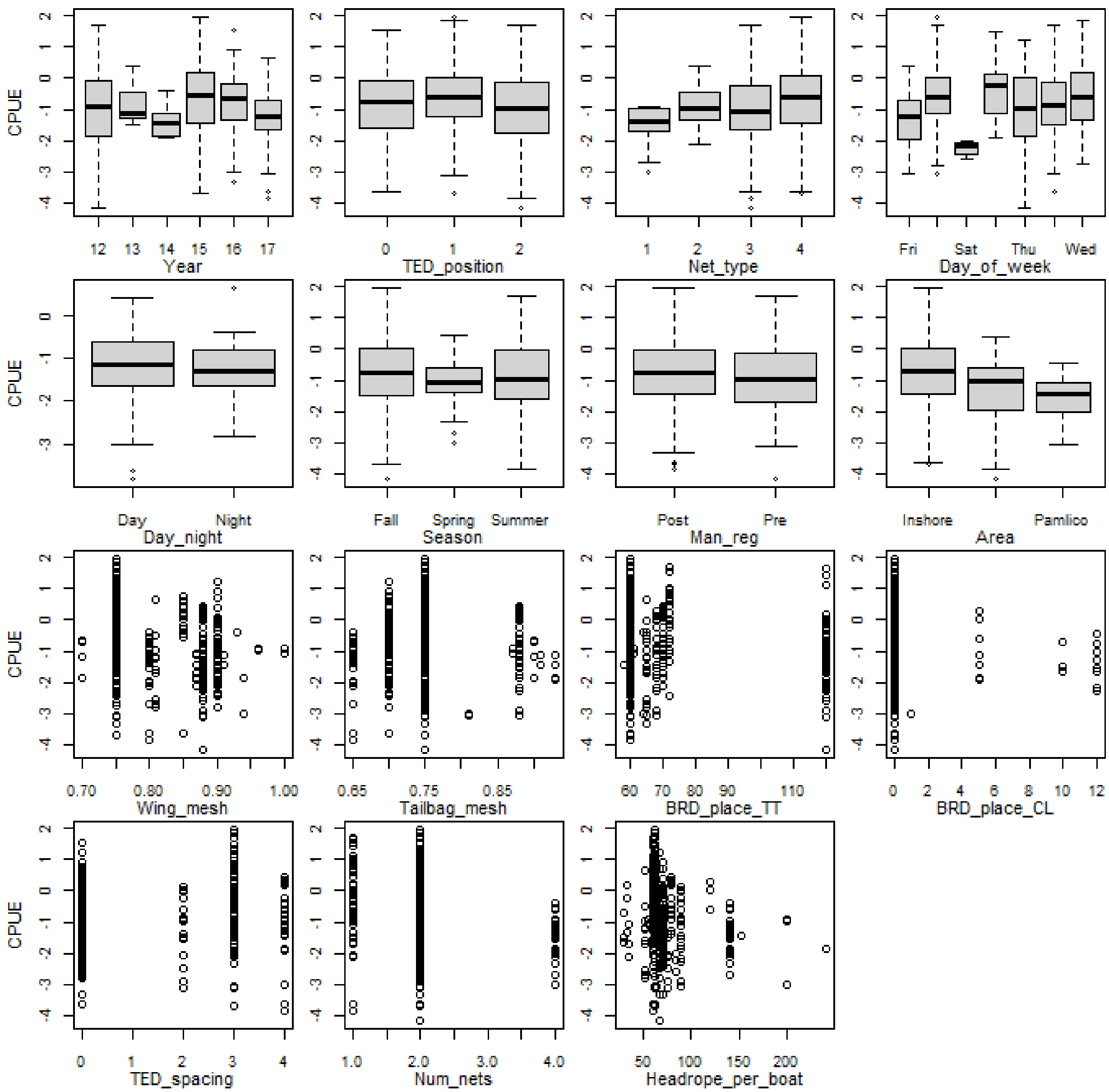


Figure 2.4.A.16. Plots of log(CPUE) against each potential predictor variable for white shrimp.

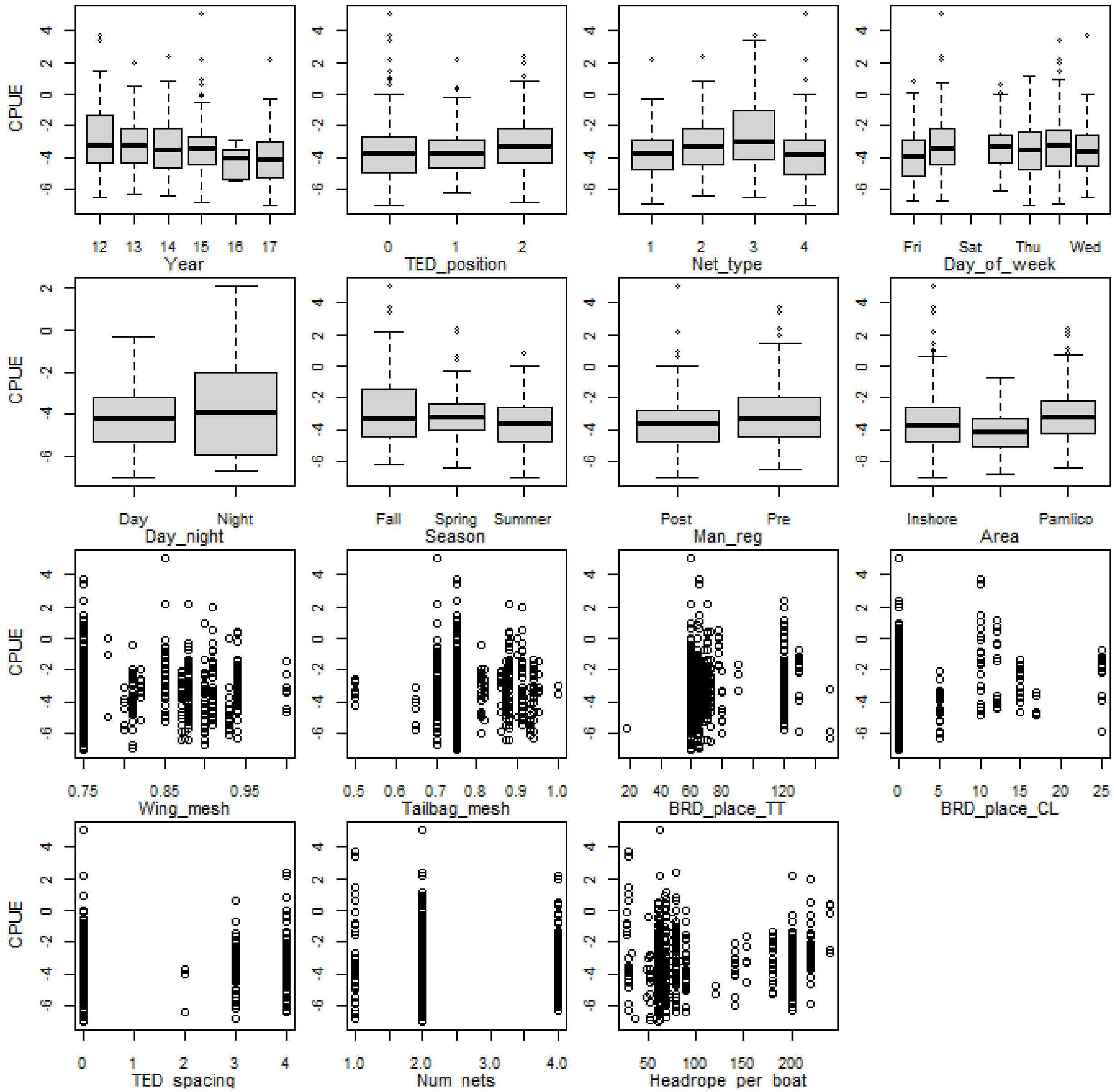


Figure 2.4.A.17. Plots of log(CPUE) against each potential predictor variable for blue crab.

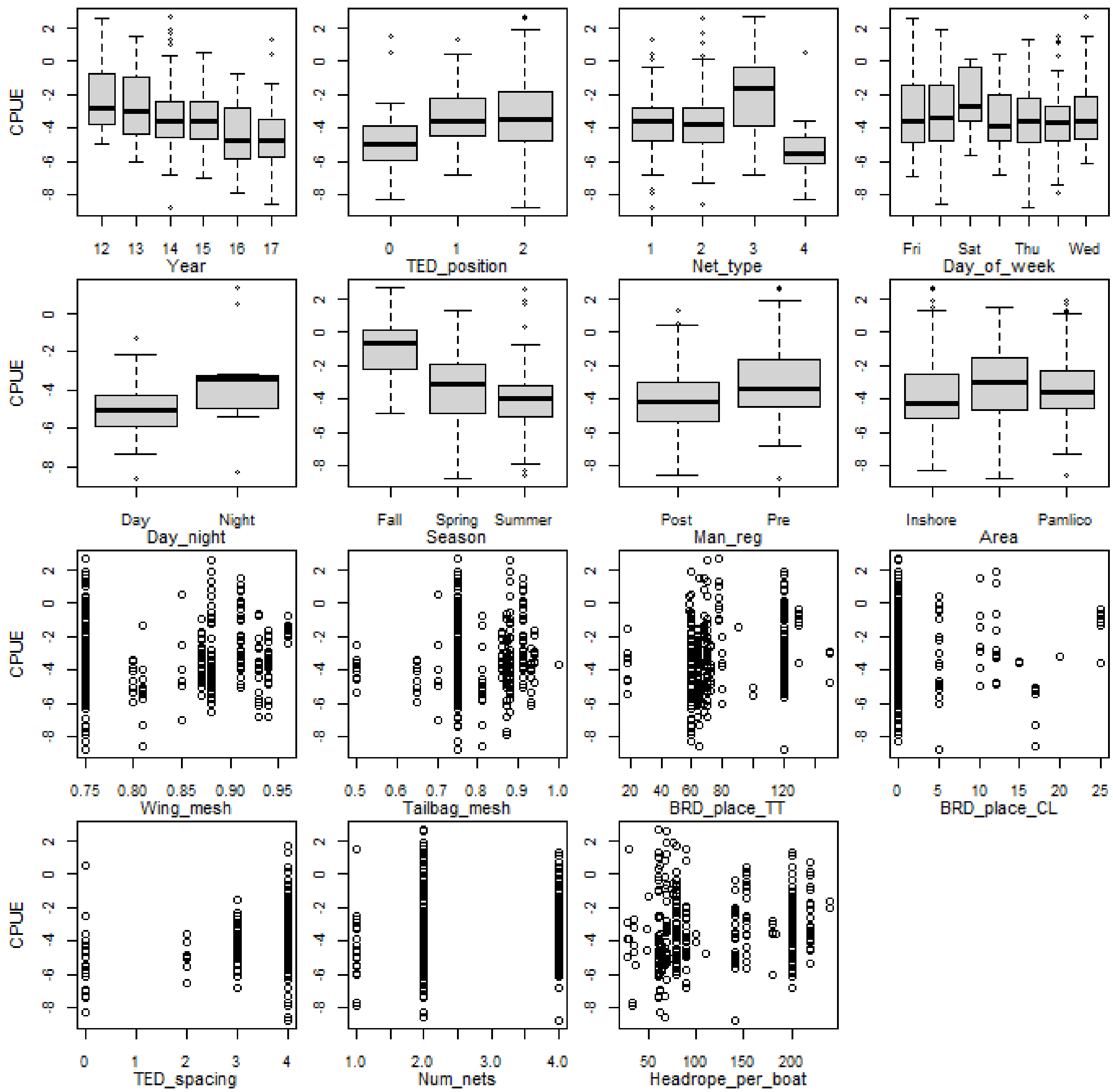


Figure 2.4.A.18. Plots of log(CPUE) against each potential predictor variable for southern flounder.

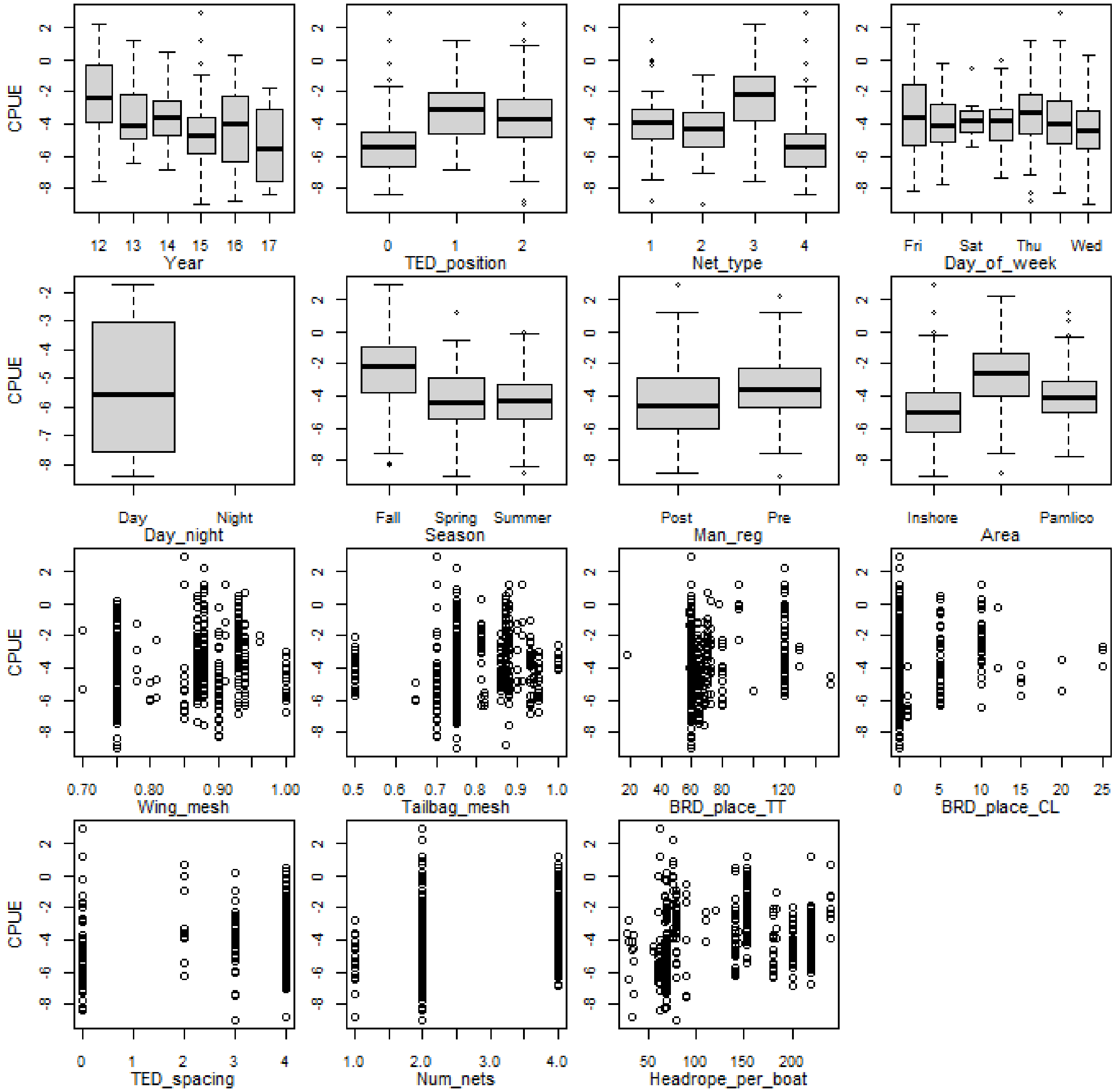


Figure 2.4.A.19. Plots of log(CPUE) against each potential predictor variable for summer flounder.

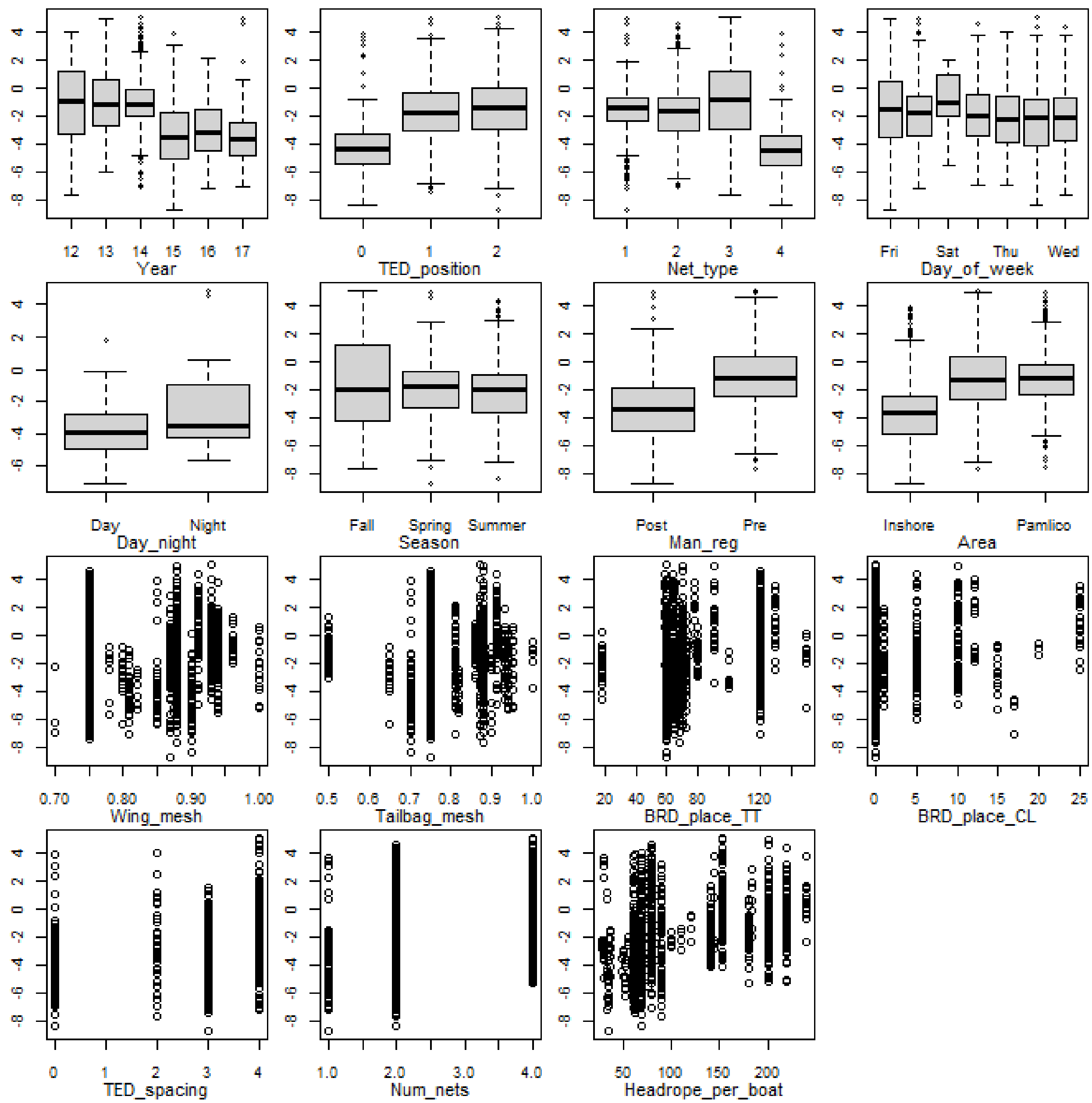


Figure 2.4.A.20. Plots of log(CPUE) against each potential predictor variable for spot.

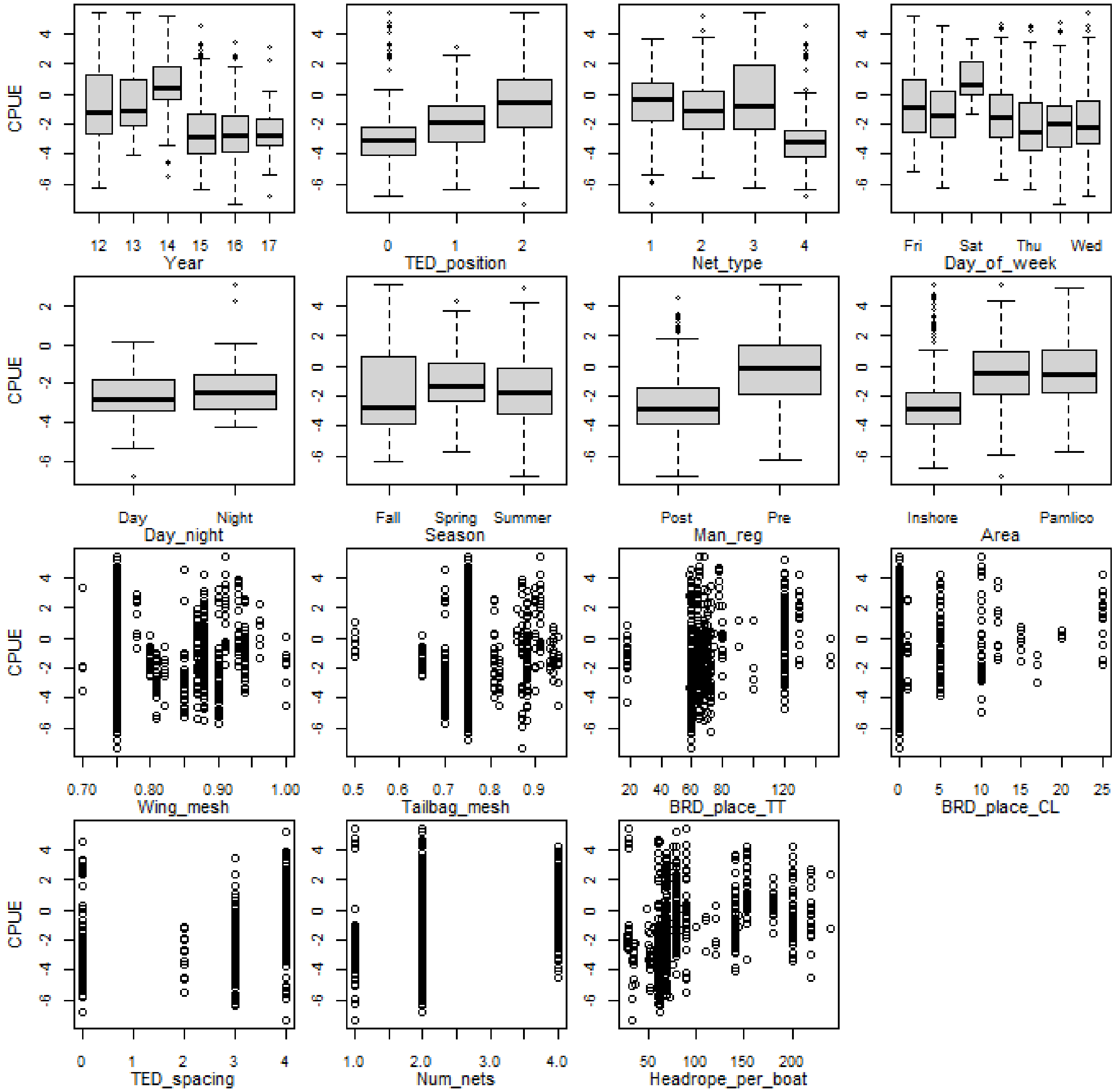


Figure 2.4.A.21. Plots of log(CPUE) against each potential predictor variable for croaker.

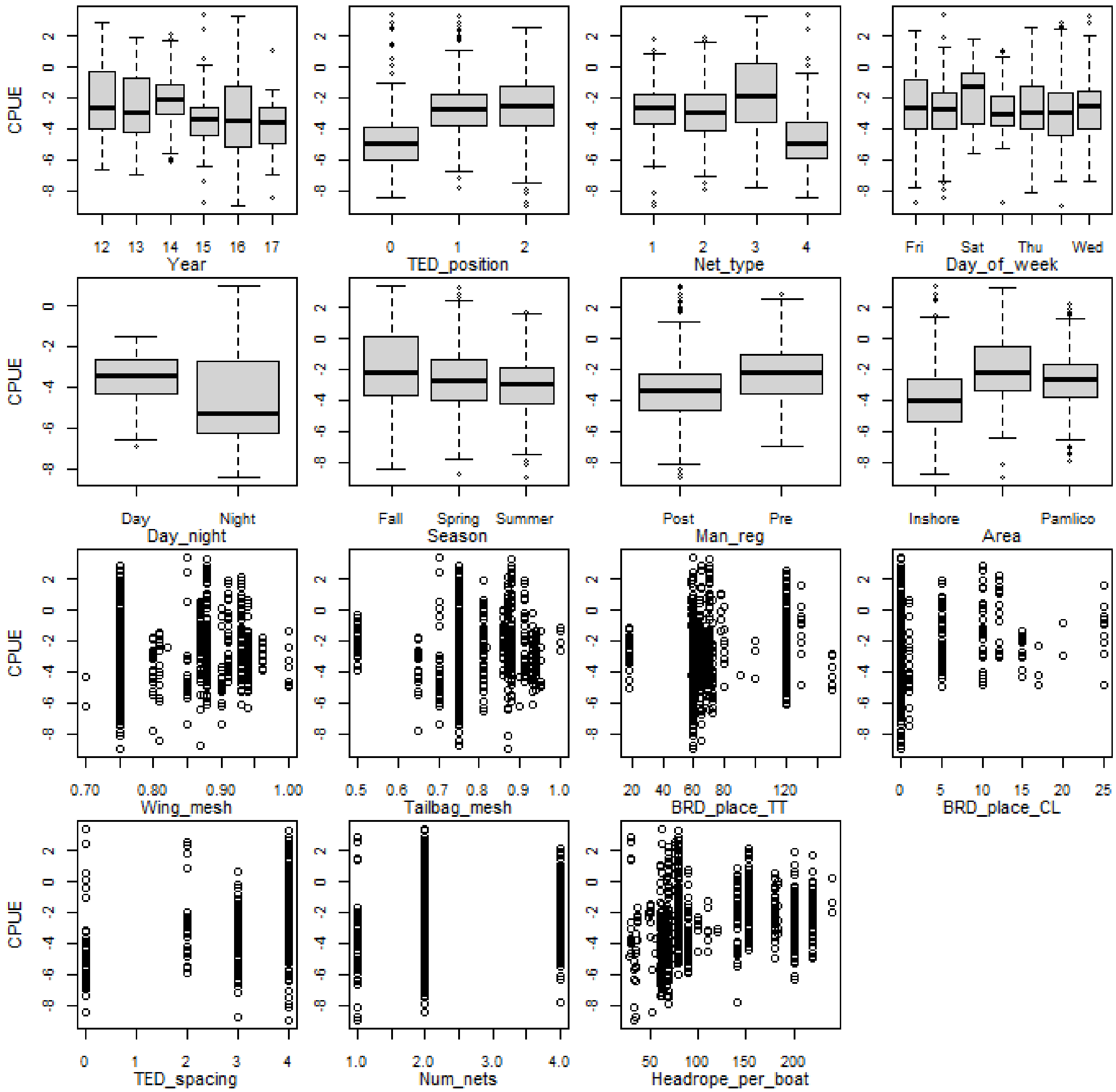
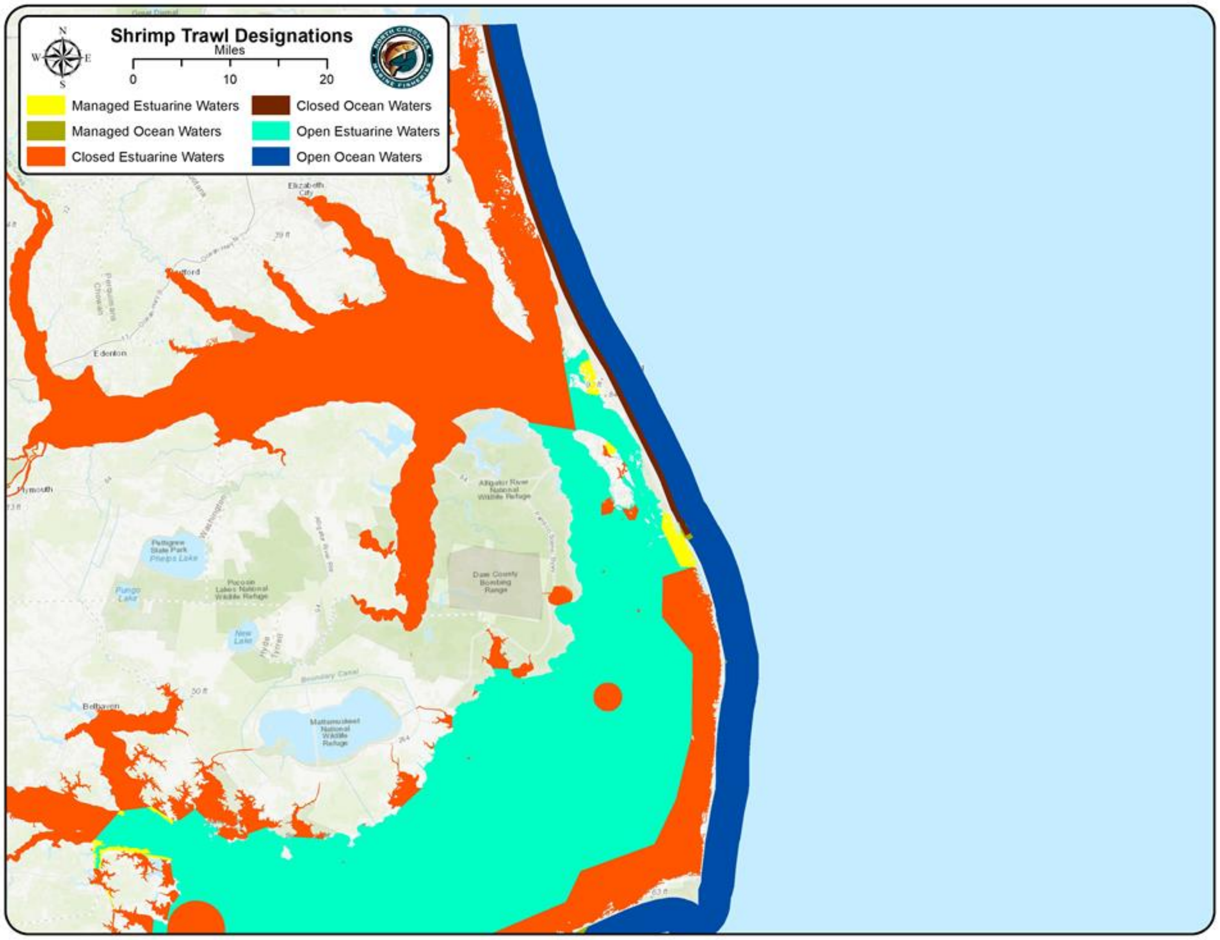
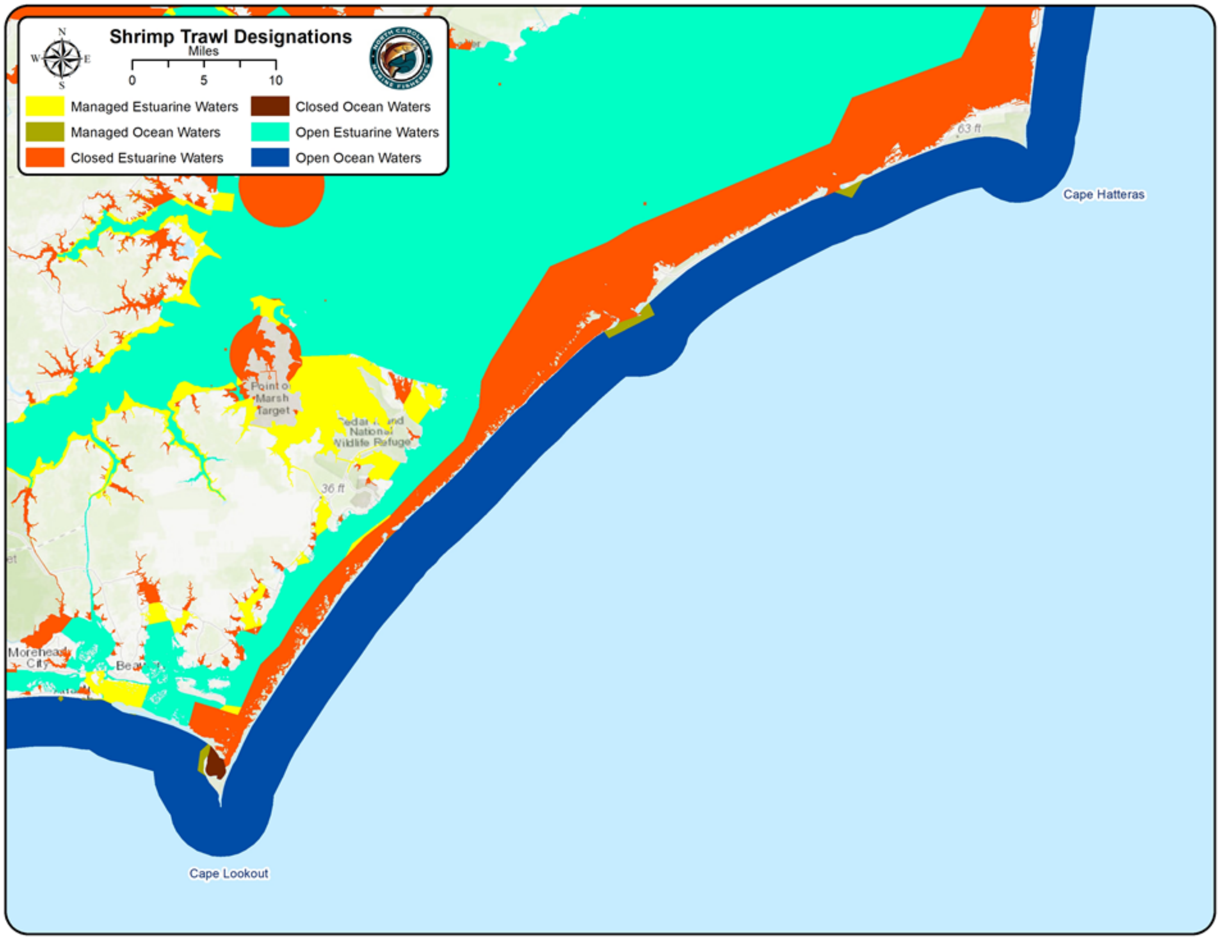


Figure 2.4.A.22. Plots of log(CPUE) against each potential predictor variable for weakfish.

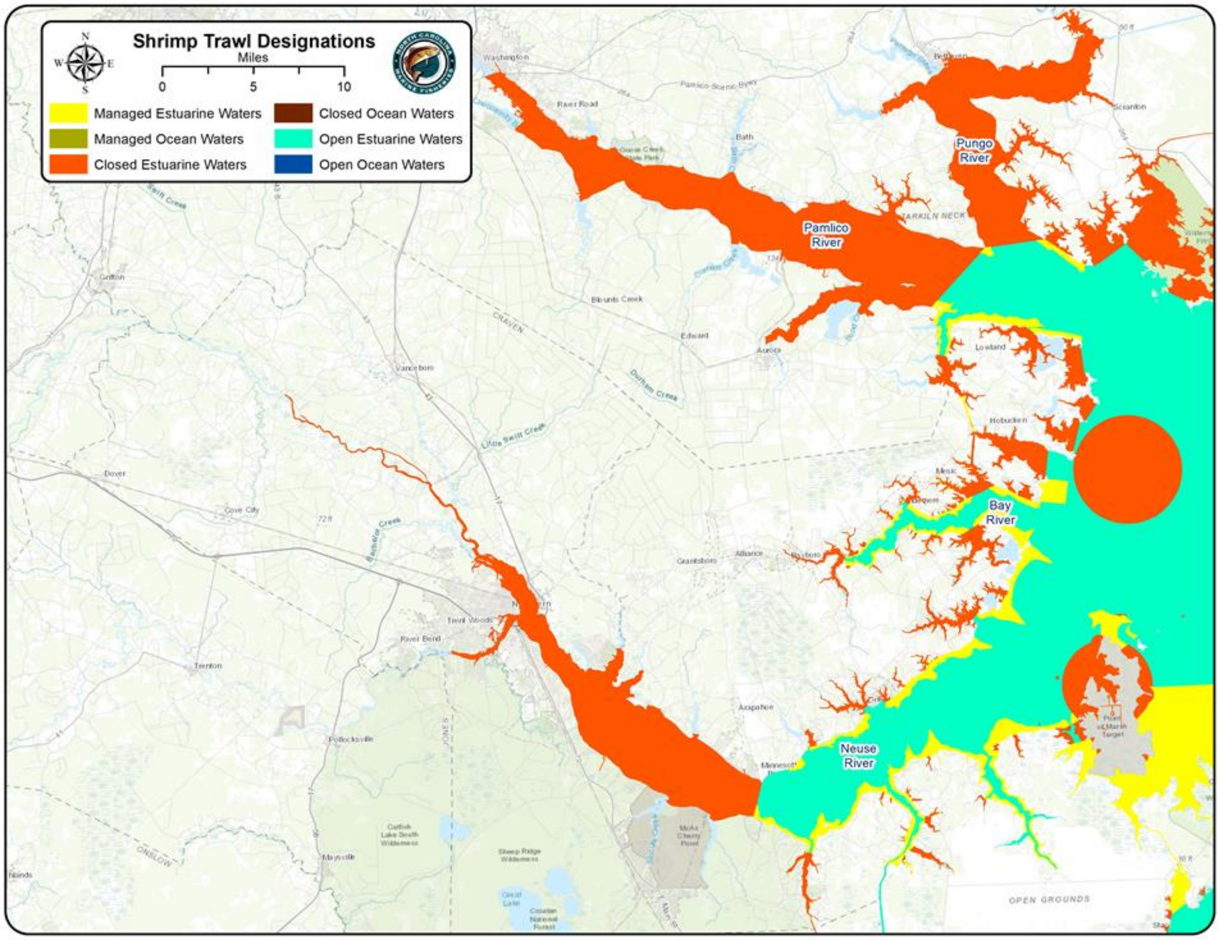
APPENDIX 3. MAPS OF CURRENT AREA CLOSURES



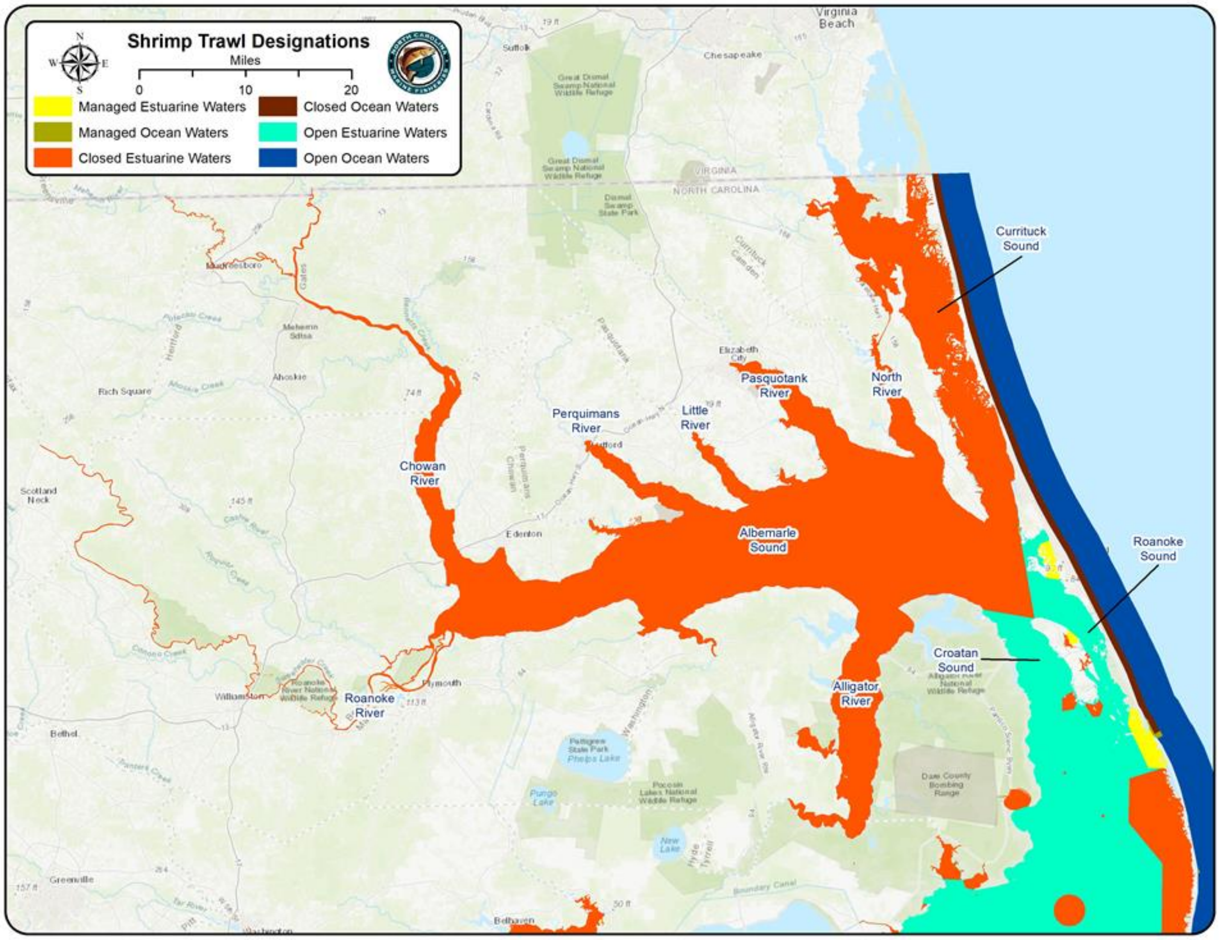
Map 3.1. Map of shrimp trawl areas in northern Pamlico Sound.



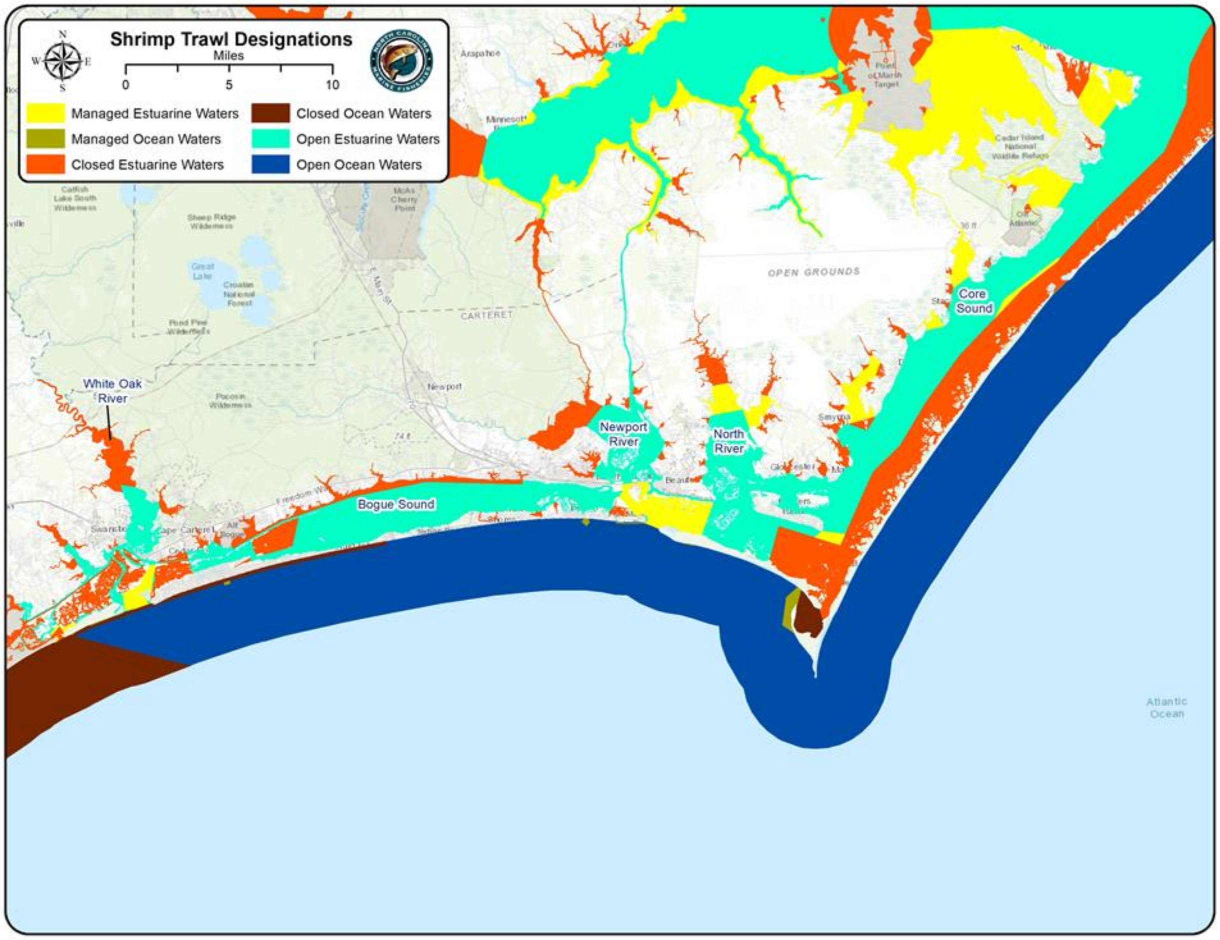
Map 3.2. Map of shrimp trawl areas in eastern Pamlico Sound Core Sound.



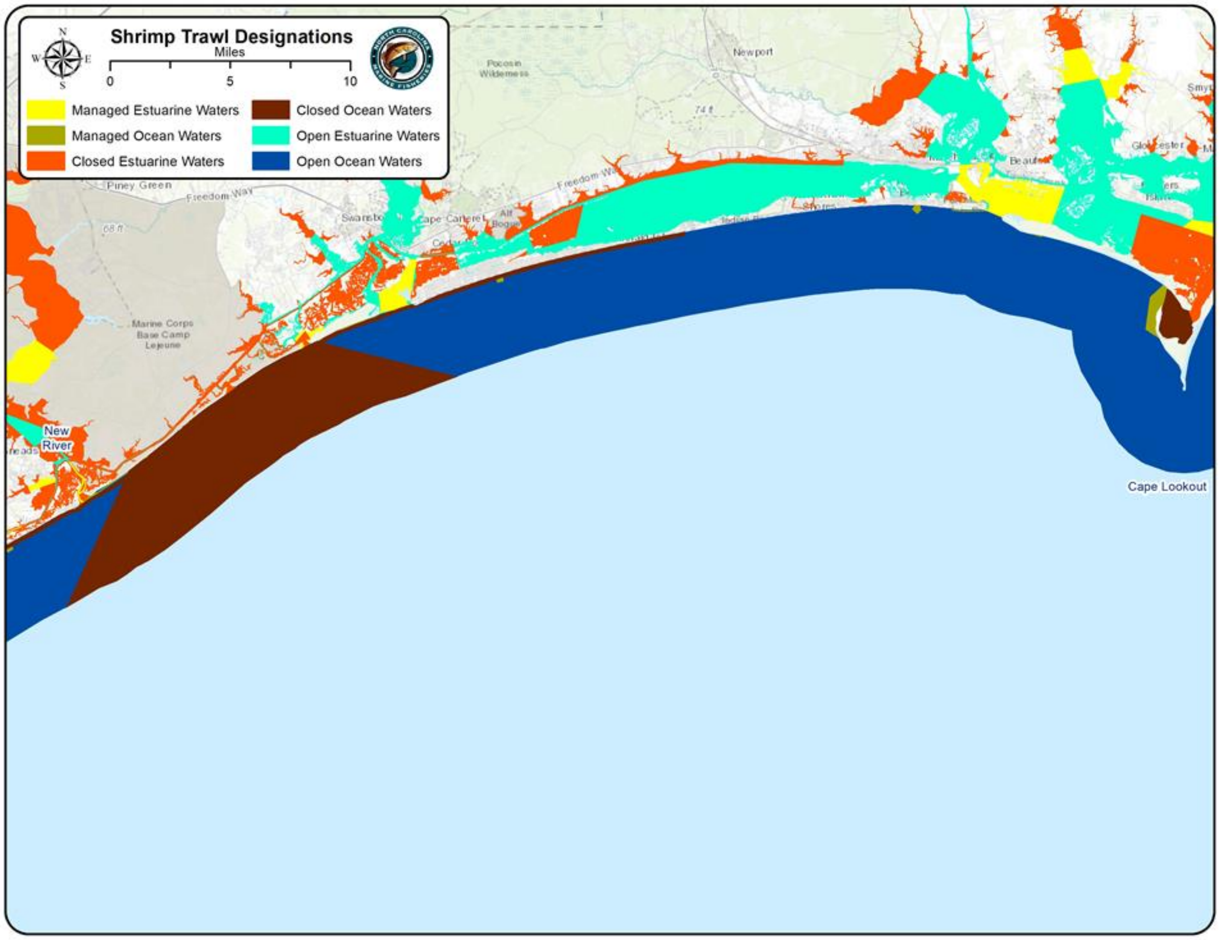
Map 3.3. Map of shrimp trawl areas in Pamlico, Pungo, Bay and Neuse rivers.



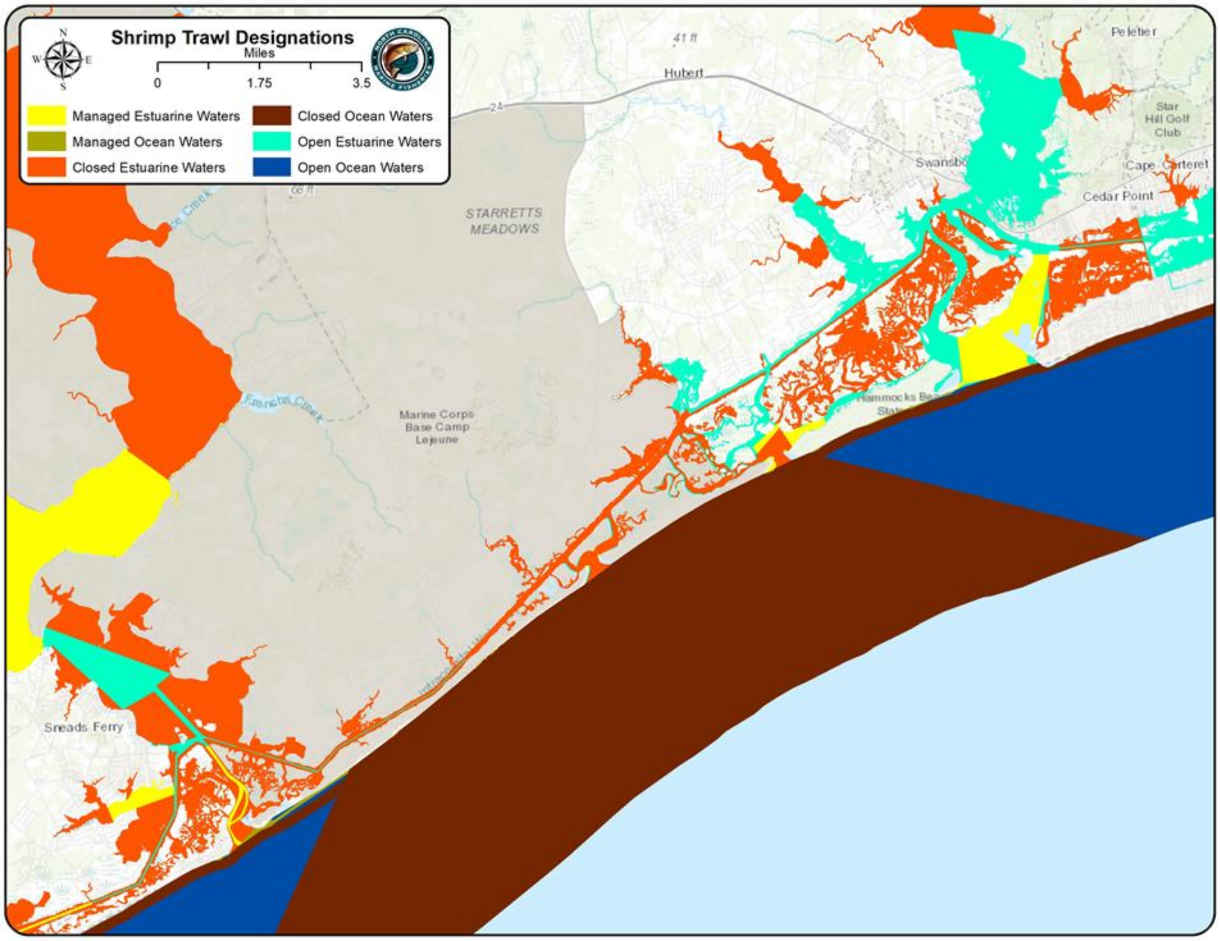
Map 3.4. Map of shrimp trawl areas north of Pamlico Sound (Croatan and Roanoke sounds).



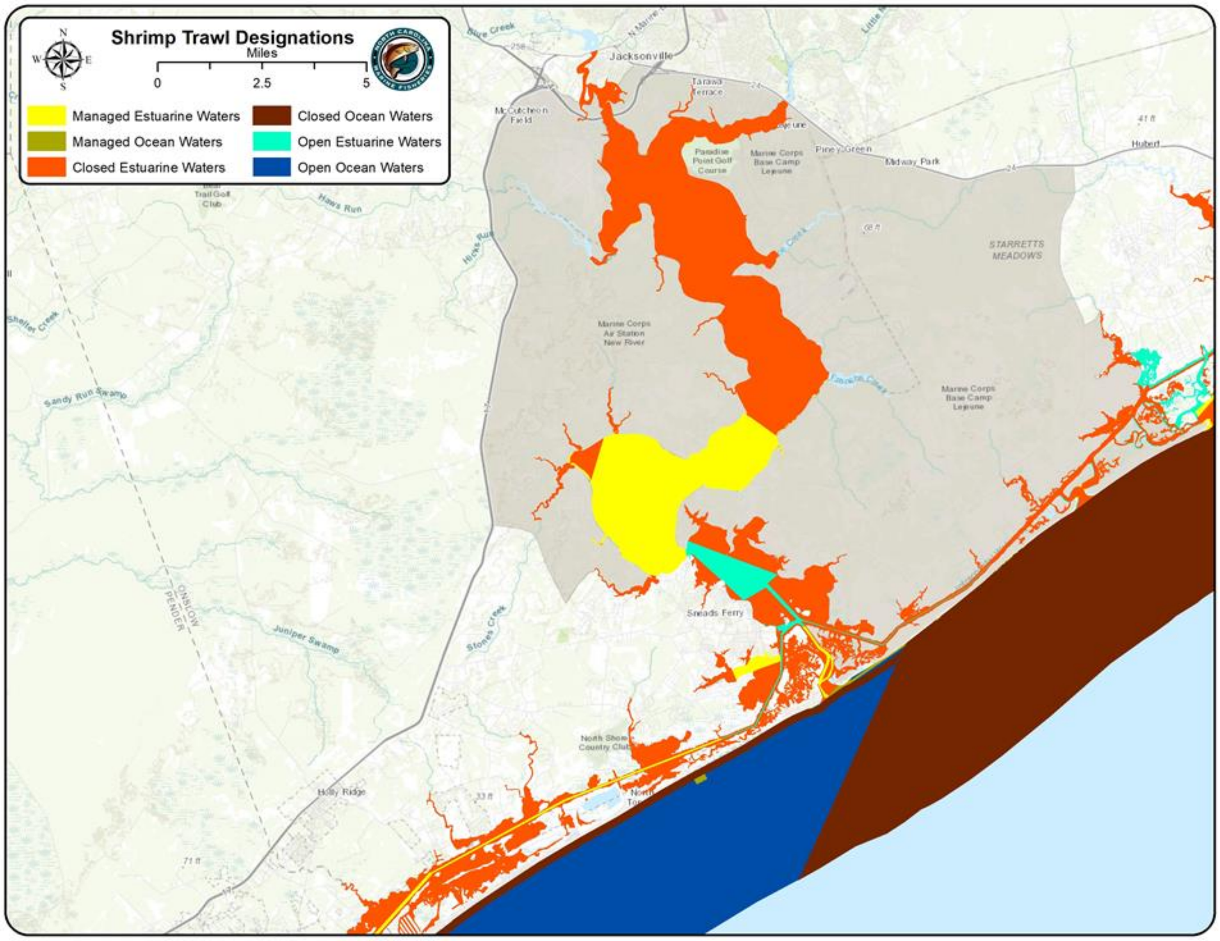
Map 3.5. Map of shrimp trawl areas from Core Sound to White Oak River.



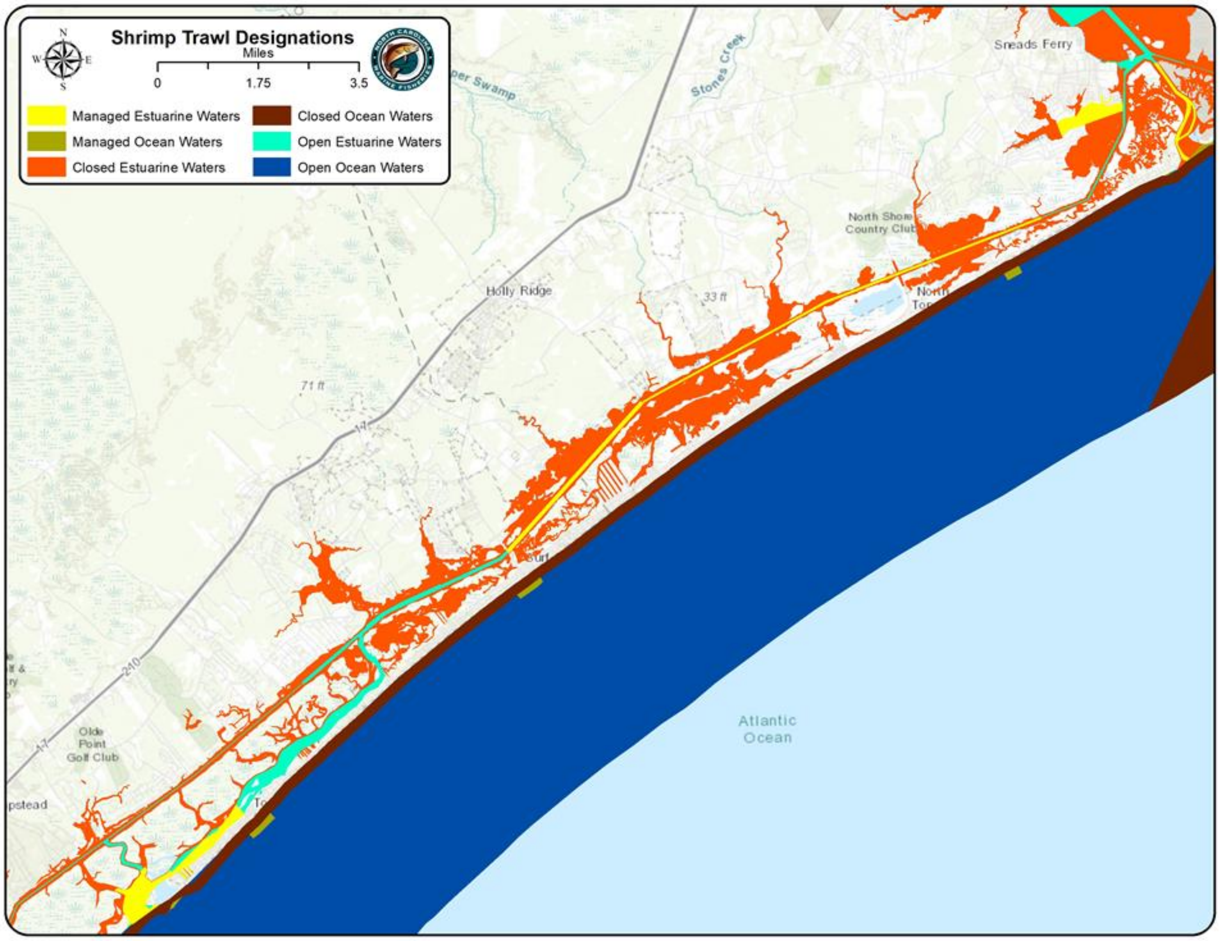
Map 3.6. Map of shrimp trawl areas from Cape Lookout to New River.



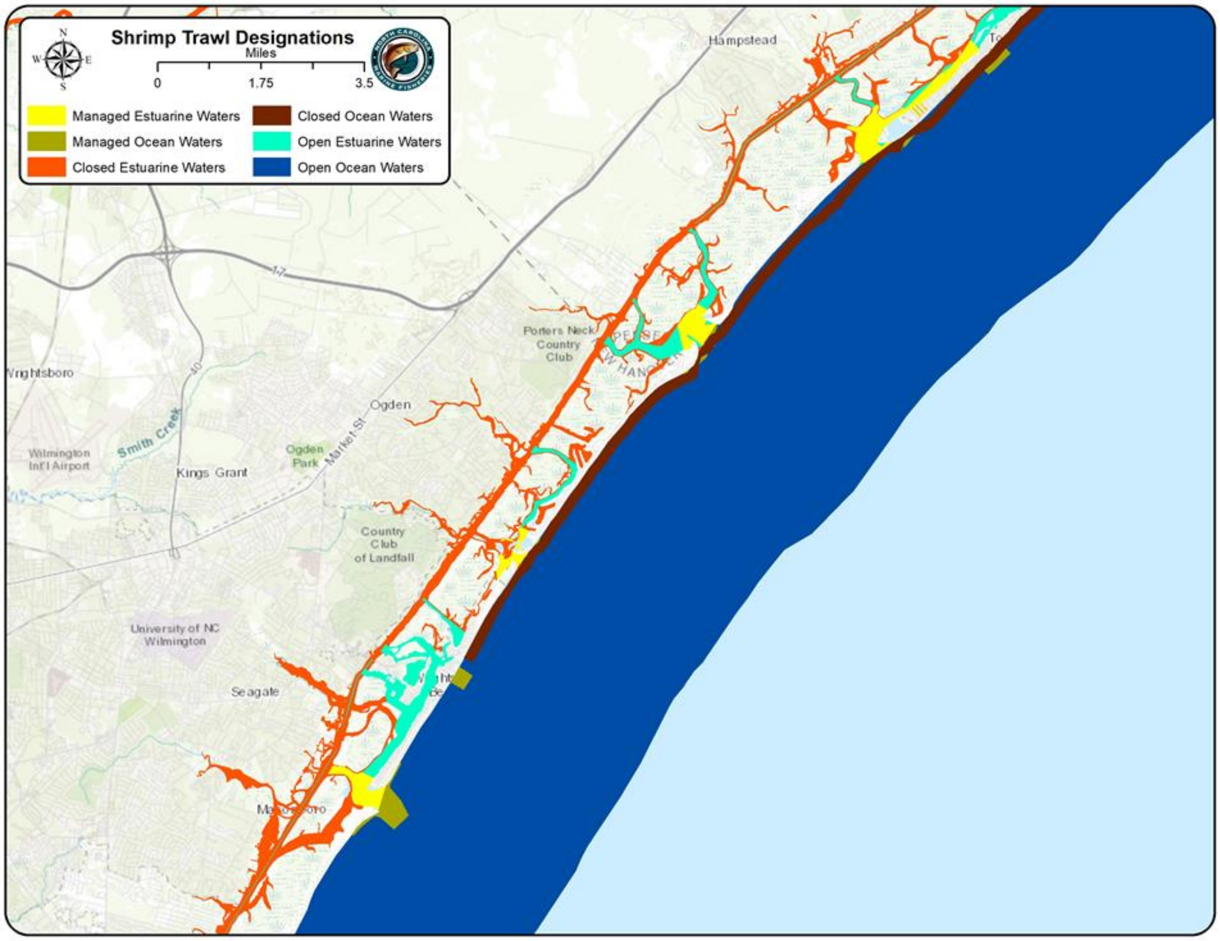
Map 3.7. Map of shrimp trawl areas from White Oak River to New River.



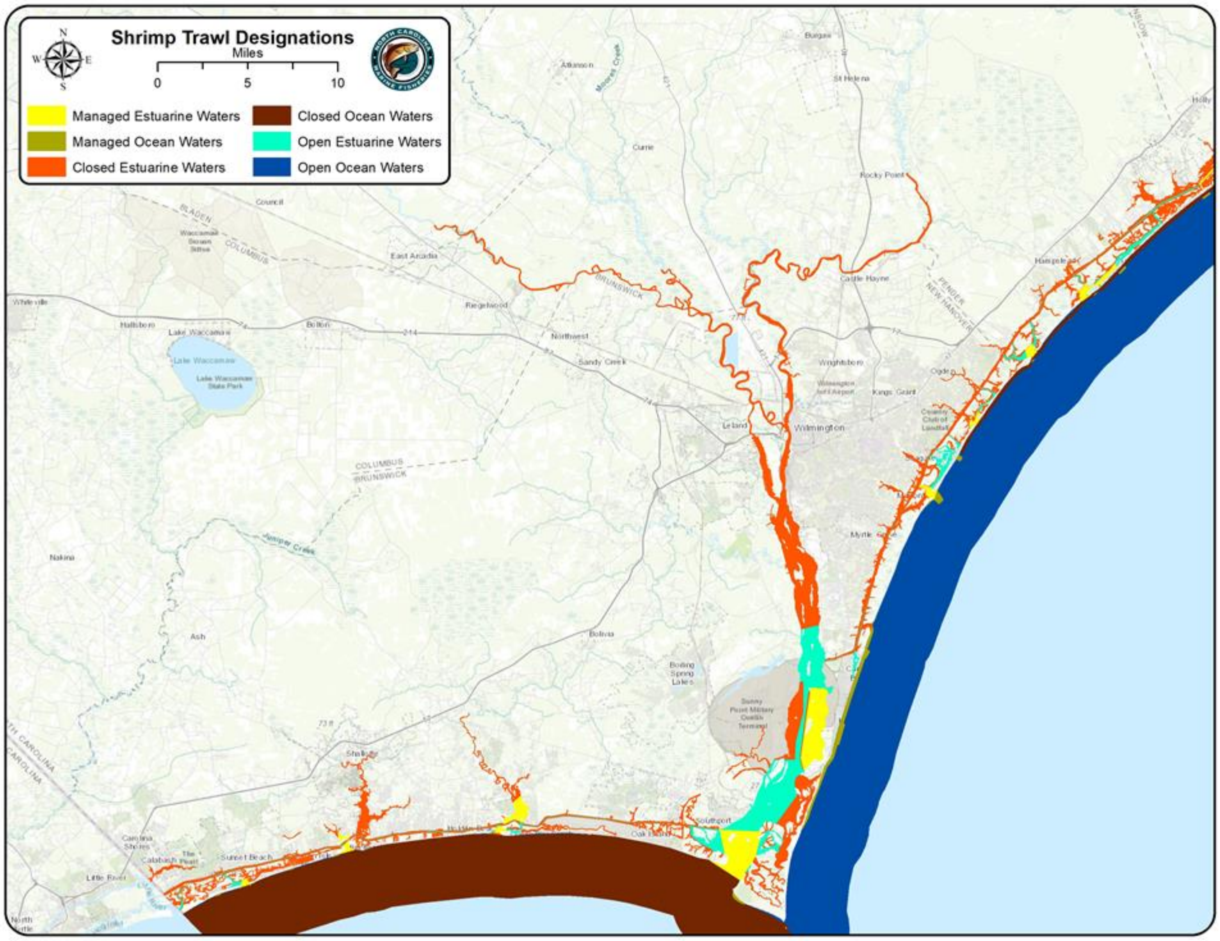
Map 3.8. Map of shrimp trawl areas in New River.



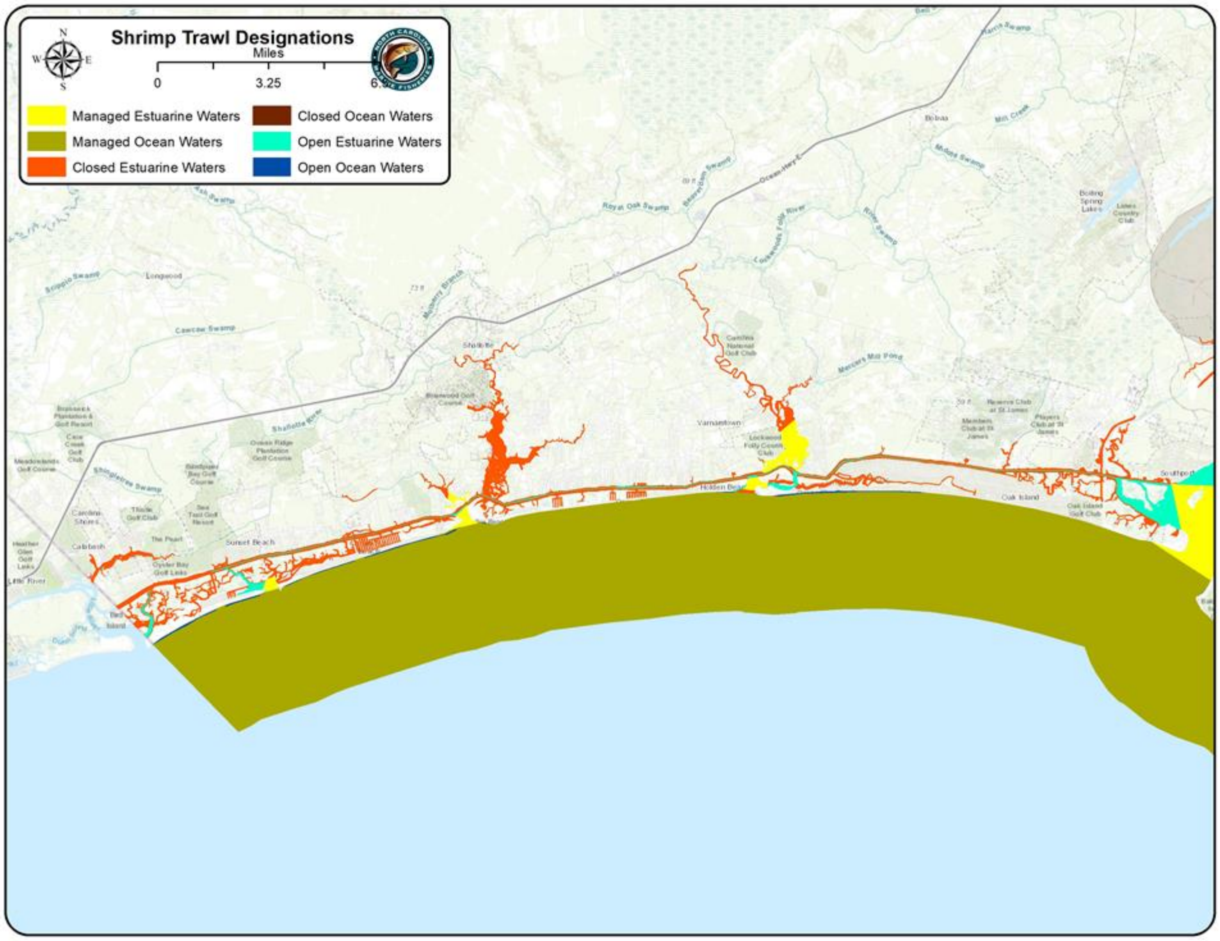
Map 3.9. Map of shrimp trawl areas from New River to Topsail Inlet.



Map 3.10. Map of shrimp trawl areas from Topsail Inlet to Wrightsville Beach.



Map 3.11. Map of shrimp trawl areas in Cape Fear River



Map 3.12. Map of shrimp trawl areas from Cape Fear River to South Carolina state line.

APPENDIX 4. COMMERCIAL, BAIT, AND RECREATIONAL SHRIMP TRAWL REGULATIONS FOR SOUTH ATLANTIC AND GULF STATES MAY 2021

Table A.4.1. Commercial food shrimp trawl regulations for South Atlantic and Gulf of Mexico states. *Unable to verify regulations with state fisheries agency.

State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
North Carolina	Pamlico Sound up to 220 ft of headrope; other inshore waters up to 90 ft headrope; no headrope limit in state ocean waters; two BRDs required in all trawl nets	Open year-round in most areas; special secondary nursery areas and other managed areas open based on biological sampling	Yes: prohibited in primary and secondary nursery areas and Albemarle Sound	
South Carolina	Up to 220 ft of footrope; BRD required in nets with 2.5" stretch mesh or less or with a headrope 16 ft or greater	Open May - Dec. in general trawl areas; open Sep. - Dec. 15 below channel net areas	Yes: mouths of St Helena, Port Royal, and Alibogue sounds and Winyah and North Santee bays	Cannot dispose of bycatch within half mile of beach; no shrimping at night
Georgia*	BRD in all nets > 16 ft headrope; TED in all nets >12 ft headrope unless hand retrieved	Open as early as May 15; close Dec 31 or may extend into Jan or Feb	No	No TED required if hand retrieved, must follow seasonal tow time restrictions
Florida*	1-2 roller frame, otter, and/or skimmer trawls depending on region; no more than 500 square feet of mesh area in net/bag; BRD and TED required	June-Oct.: no weekend shrimping; Apr-May: closed in certain counties	Yes, managed by region: North West region-yes with additional gear restrictions; Big Bend Region-yes; South West Region-Tampa Bay-yes; South East Region-Biscayne Bay-no; North East Region-yes, tributaries of rivers closed	
Alabama	Up to 50 ft headrope and no more than 2 trawls; no restrictions offshore; TED required	Closed May 1 - June 1, other specific seasonal closures	Yes: Mobile Bay, parts of Mississippi Sound, and other smaller bays	Minimum size limit 68 count head-on or lower

State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
Mississippi	Up to 50 ft headrope if using one trawl net; up to 25 ft of headrope per net if using two trawl nets; no more than two trawl nets may be used; trawl doors: 8 ft length, 43 in. high; TED required	Opens in May/June; closes: Jan. 1 north of IWW and April 30 south of IWW	Yes: all inside bays and rivers closed and closed in Mississippi Sound within 1/2 mile of mainland shoreline; closed within 1 mile perimeter around barrier islands eight miles from mainland shoreline	Minimum size limit 68 count head-on
Louisiana	Inshore: up to 50 ft headrope if using one trawl net; up to 25 ft headrope per net if using two trawl nets; no more than two trawl nets may be used; max trawl door size: 8' long x 43" high; Offshore to 3 miles: up to 130 ft headrope max; Breton and Chandeleur Sounds - 2 trawl nets, with no more than 65 ft of headrope each; EEZ: up to 4 trawls, any size; Mesh size restrictions - 5/8" bar of 1-1/4" stretched, 3/4" bar or 1.5" stretched in Vermilion-Teche Basin in fall shrimp season; BRD and TED required in federal waters, TED required in trawl nets fishing state waters	Spring inshore season: typically, May - early July; fall inshore season: Aug - Dec; offshore: open year-round; exemptions (live bait) close late fall-early winter	Yes: managed by zones	Minimum size limit of 100 count head-on for white shrimp, except Oct. 15 - third Monday in Dec.; crab trap interactions requirements; night shrimping prohibited in some areas (Vermilion-Teche and Calcasieu Basins); restricted areas in refuges and WMAs;
Texas	Major bays: spring - one otter trawl net 40-54 ft wide depending on door size, one beam trawl up to 25 ft; fall - one trawl up to 95 ft wide; winter - same as spring. BRD and TED required. Minimum mesh size: spring - 1.3 in.; fall - Aug. 15-Oct. 31 1.75 in., Nov. 1-Nov. 30 1.3 in.; winter: 1.3 in.	Major Bays: Spring - May 15 - July 15; Fall - Aug. 15 - Nov. 30; Winter (south of Colorado River only) - Feb. 1 - April 15.	Yes	Daily fishing time: spring and fall - 30 minutes before sunrise to 30 minutes after sunrise; winter - 30 minutes after sunset to 30 minutes before sunrise. Harvest limit: spring - 800 lb; fall - Aug. 15-Oct. 31 50 count heads on per pound, Nov. 1-Nov. 30 no limit; winter - no limit.
	Inside 3 nm: Southern and Northern zones - up to two trawl nets, each net 71-89 ft wide depending on door size, minimum mesh size 1.75 in., BRD and TED required.	Southern: July 16-Nov. 30; Northern: Feb. 16-May 15 and July 16-Nov. 30.		Daily fishing time: Southern and Northern zones 30 minutes before sunrise to 30 minutes after sunset.
	3-5 nm: Southern and Northern zones - minimum mesh size 1.75 in., BRD and TED required.	Southern: July 16-Nov. 30; Northern: Feb. 16-May 15 and July 16-Nov. 30.		Daily fishing time: Southern and Northern zones 30 minutes before sunrise to 30 minutes after sunset.

State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
Texas cont.	5-9 nm: Southern and Northern zones - minimum mesh size 1.75 in., BRD and TED required.	Southern and Northern zones: July 16-Nov. 30 and Dec. 1-May 15.		Daily fishing time: Southern and Northern zones 30 minutes before sunrise to 30 minutes after sunset.
	Seabob fishery: one otter trawl net 48-62 ft wide depending on door size, minimum mesh size 1.3 in., BRD and TED required.	Northern zone only: Dec. 1-May 15 and July 16-Nov. 30.		Daily fishing time: 30 minutes before sunrise to 30 minutes after sunset. No more than 10% in weight or number any other species of shrimp.

Table A.4.2. Commercial bait shrimp trawl regulations for South Atlantic and Gulf of Mexico states. *Unable to verify regulations with state fisheries agency.

State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
North Carolina	One trawl net with up to 40 ft headrope	Same as commercial	Same as commercial	Allowed on weekend with permit; live well required; no more than 1-gallon dead shrimp
South Carolina	Same as commercial	Same as commercial	Same as commercial	Same as commercial
Georgia*	One trawl net with up to 20 ft headrope	Open year-round	Yes: 60 bait zones located in middle and upper estuaries	TED and BRD are not required; 50-quart harvest limit; less than 10% dead shrimp
Florida*	Roller frame trawl only except 1 otter trawl in North East Region with 5/8 in. body and 1/2 in. cod end	North East Region closed Apr - May	Yes	Live well required; no more than 5-gallon dead shrimp
Alabama	One trawl net with up to 50 ft headrope; trawl net cannot exceed 16 ft headrope in areas temporarily closed to commercial shrimping or in exclusive bait areas	Closed May 1 - June 1	Yes: same as commercial and exclusive bait areas	Exclusive bait areas open 4 a.m. to 10 p.m.; live well or aerator required; two standard shrimp baskets live or dead harvest limit; 20-minute maximum tow time
Mississippi	One trawl net no larger than 16 ft headrope and 22 ft footrope, except areas west of Bayou Caddy where trawl net may be up to 25 ft headrope and 32 ft footrope	Open year-round	Yes: major bays closed; live bait catcher boats can trawl within 1/2 mile of the mainland shoreline	Minimum size of 100 count or lower; no more than 30 lb dead shrimp; daytime only; 25-minute maximum tow time

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State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
Louisiana	One trawl net no more than 25 ft along the cork line and 33 ft along the lead line; two skimmer nets with individual nets no more than 16 ft measured horizontally, 12 ft measured vertically, or 20 ft measured diagonally	Open year-round	Yes	$1,000 cash bond, background check, facility inspection, 12" signage, and VMS required
Texas	One trawl net with a 40 to 54 ft headrope	Open year-round	Yes: major bays	200 lb harvest limit; Nov. - Aug. 50% must be live; Aug. - Nov. all heads must be attached

Table A.4.3. Recreational shrimp regulations for South Atlantic and Gulf of Mexico states. *Unable to verify regulations with state fisheries agency.

State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
North Carolina	One trawl net with up to 26 ft headrope; BRDs required; TED required for mechanical retrieval	same as commercial	same as commercial	Recreational Commercial Gear License (RCGL) required; harvest limit of 48-quart heads-on or 30-quart heads-off per person; up to two limits per vessel if more than one RCGL holder onboard
South Carolina	same as commercial	same as commercial	same as commercial	Trawling for personal use is restricted to the same license requirements, areas, and seasons as commercial
Georgia*	One trawl net with up to 10 ft headrope	Open year-round	60 bait zones located in middle and upper estuaries	Harvest limit of 2 quarts per person or 4 quarts per vessel; no recreational trawling for food shrimp
Florida*	Dip net, cast net, push net, frame net, shrimp trap, and seine only	Closed season: April and May closed in Nassau, Duval, St. Johns, Putnam, Flagler, and Clay counties.	No	Harvest limit of 5-gallon heads-on limit
Alabama	One trawl net with up to 16 ft headrope; hand retrieval only; TED not required	Closed May 1 - June 1	same as commercial and exclusive bait areas	Harvest limit of 5 gallon heads-on per person in non-bait areas; harvest limit of 1 gallon heads-on per person in exclusive bait areas
Mississippi	One trawl net with up to16 ft headrope; TED not required for hand retrieval	same as commercial	same as commercial	same as commercial

State	Gear Restrictions	Season	Estuarine Trawling Allowed	Miscellaneous
Louisiana	One trawl net with up to 16 ft or 25 ft headrope (separate licenses); minimum mesh size of 5/8" bar or 1-1/4" stretched; Vermilion-Teche Basin minimum mesh size of 3/4" bar or 1-1/2" stretched	same as commercial	same as commercial; must be 500' beyond shoreline around Grand Isle	Minimum size limit of 100 ct for white shrimp, except Oct 15 - third Monday of Dec; harvest limit of 100 lb per boat (for headrope 16 ft or less) or 250 lb limit per boat (for headrope 16-25 ft headrope)
Texas	Maximum of 20 ft width between trawl doors	Major bays (excluding closed areas): May 15 - July 15 and August 15 - November 30. Gulf: same as commercial.	same as commercial	Bays: harvest limit of 15 lb heads-on per person per day; Gulf: harvest limit of 100 lb heads-on per boat per day; required to have a valid recreational fishing license; fishing hours are 30 minutes before sunrise to 30 minutes after sunset

APPENDIX 5. SUMMARY OF ADVISORY COMMITTEE AND NCDMF RECOMMENDATIONS FOR ISSUE PAPERS IN THE AMENDMENT 2 OF THE SHRIMP FISHERY MANAGEMENT PLAN

This section to be completed prior to final adoption of the plan.