Strategic Habitat Area Nominations for Region 4:

The Cape Fear River Basin in North Carolina

FINAL REPORT

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By

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GLOSSARY OF ACRONYMS

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

EXECUTIVE SUMMARY

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

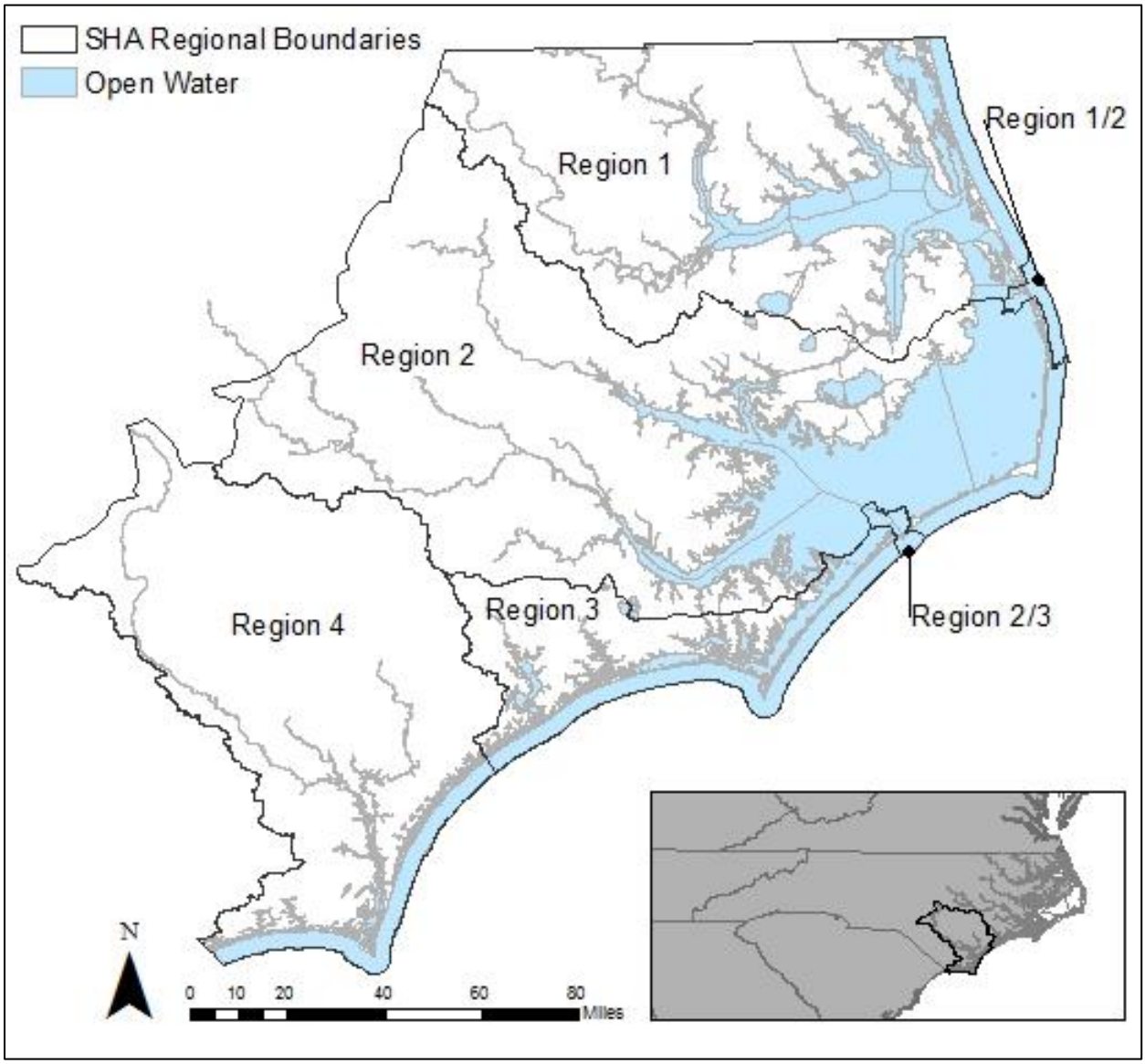
1 INTRODUCTION

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

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

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

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



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

1.1 Geographic Scope of Region 4

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

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

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

Map 2. Major water bodies in Region 4.

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

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

1.2 Land Use

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

The large population increase puts stress on the adjacent ecosystem. For example, of the coastal river basins, the Cape Fear, which includes the southern estuaries of Pender and New Hanover counties, had the second greatest acreage of impacted wetlands based on 401 permit records, from FY 2000- FY 2014. Increasing development stresses shell bottom habitat through point and nonpoint sources bringing sediment and other pollutants to shellfish waters. In 2014 48% of

shellfish harvest waters in the southern counties (Onslow through Brunswick counties) were closed due to bacterial contamination. Despite multiple anthropogenic threats and large areas closed to harvest, 45% of the total landings in North Carolina came from the southern counties in 2013 (DEQ 2016), which further impacts the habitat. In the low salinity and fresh waters of the Cape Fear River, runoff from agriculture, concentrated animal feeding operations (CAFOs), and industrial discharges is the primary water quality threat. Since 2009, algal blooms of toxic *Microcystis* have been occurring in the Cape Fear River and been concentrated between Lock and Dam 1 and upstream of Lock and Dam 3. Obstructions to anadromous fish passage from dams are also a significant concern in the Cape Fear River.

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

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

1.3 Identification of Priority Species

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

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

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

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

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

2 METHODOLOGY

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

2.1 Natural Resource Targets

In this analysis, natural resource targets (NRTs) are defined as the habitats that represent essential or unique components of the fisheries ecosystem. Natural resource targets vary by

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

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

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

2.1.1 Hard Bottom

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

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

2.1.2 Submerged Aquatic Vegetation

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

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

2.1.3 Shell Bottom

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

Other sources of data were incorporated into the shell bottom target, including cultch planting

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

2.1.4 Submerged Aquatic Vegetation and Shell Bottom

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

2.1.5 Low-Elevation Uplands

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

2.1.6 Wetlands

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

2.1.7 Wetland Edge

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

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

2.1.8 Streams

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

2.1.9 Soft Bottom

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

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

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

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

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

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

2.1.10 Rare or Listed Species

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

2.2 Alteration Factors

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

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

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

*Based on existing GIS layers and factored as presence/absence

**Calculated as the # of a facility per HU

***National Pollutant Discharge Elimination System – Relativized proportion of development/agricultural land use per HU

2.2.1 Natural Resource Targets and Alteration Factors

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

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

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

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

beaches with long term storm protection projects.

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

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

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

2.2.2 Hydrological Alterations

2.2.2.1 Culvert-Obstructed Areas

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

2.2.2.2 Impoundments

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

2.2.2.3 Bridge Constrictions

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

2.2.2.4 Bulkheads and Riprap

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

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

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

2.2.2.5 Dredged Channels

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

2.2.2.6 Ditched/Drained

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

2.2.2.7 Canals and Boat Basins

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

2.2.3 Water Quality and Land Use Alterations

2.2.3.1 Major and Minor NPDES

The major and minor NPDES alteration factor was derived from NPDES sites locations provided by DWR (2014 data). Major NPDES sites in the region included municipal wastewater discharges such as those for the cities of Carolina Beach, Wilmington, Elizabethtown, Fayetteville, and Dunn, and the counties of Brunswick and Harnett, and industrial process and commercial wastewater discharges such as those for the Brunswick and Sutton power plants, Riegelwood papermill, and other manufacturers. Minor NPDES sites were more numerous and variable in type including water plants and water conditioning, municipal, industrial process and commercial, groundwater remediation. It is difficult to determine the area of influence for a point source without a detailed hydrologic model. Therefore, major and minor NPDES sites

were summarized by HU to approximate the measure of alteration. The number of major and minor NPDES within HUs was then scaled by the maximum number occurring in the region, and the relative amount was used to calculate the relative severity of alteration. Major NPDES were given high alteration scores than minor NPDES to account for the scale of impact.

2.2.3.2 Marinas

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

2.2.3.3 Animal Operations

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

2.2.3.4 Developed Land Use

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

2.2.3.5 Agricultural Land Use

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

2.2.3.6 Prohibited Shellfish Harvest

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

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

2.2.3.7 Piers and Docks

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

2.2.4 Physical Disturbance

2.2.4.1 Trawling

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

2.2.4.2 Mechanical Clam Harvest Areas

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

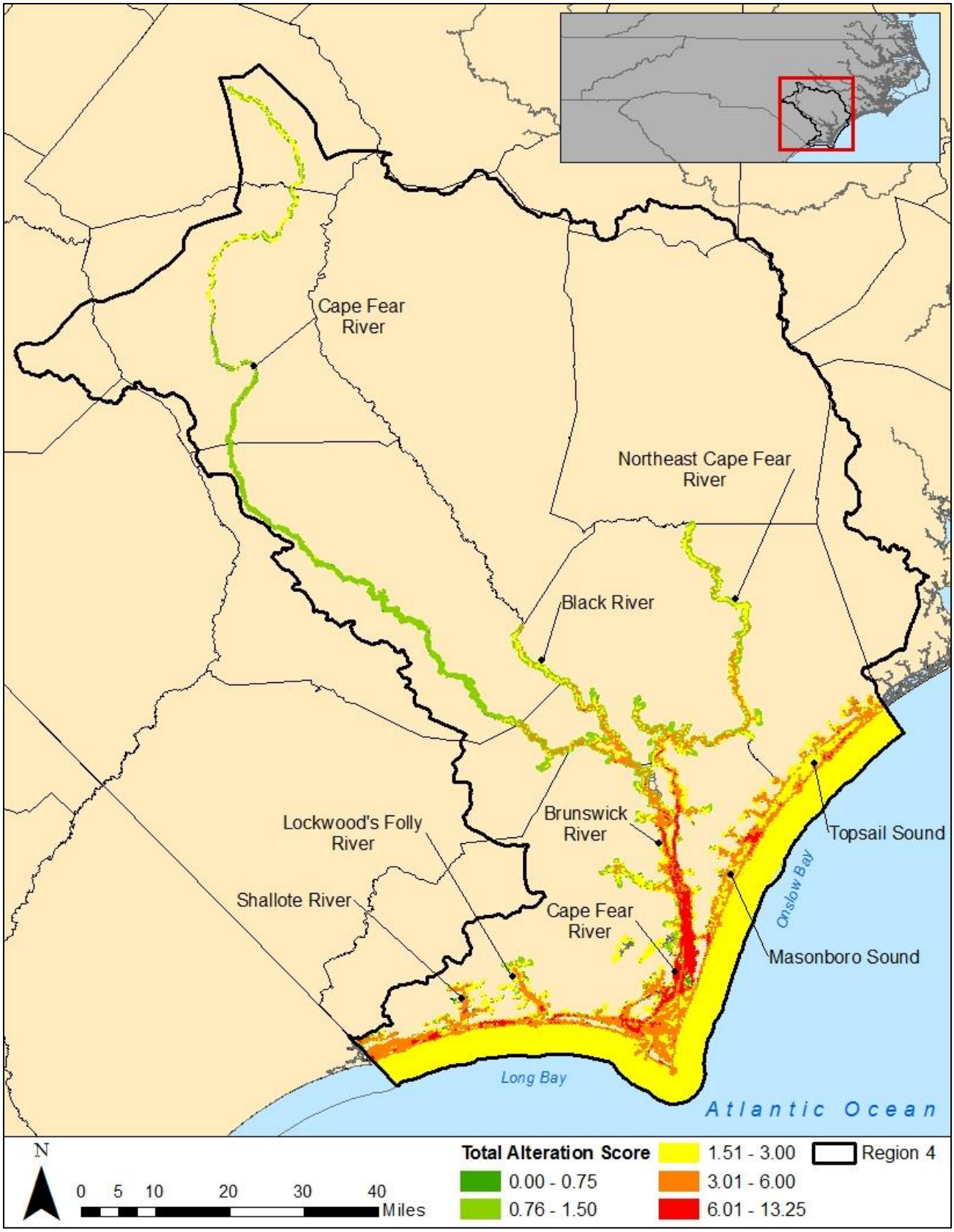
Table 4. Daily mechanical hard clam harvest limits by water body (DMF 2017).

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

2.2.5 Total Alteration/Cumulative Impacts

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

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



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

2.3 Marxan Analysis

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

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

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

2.3.1 Sensitivity Analysis

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

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

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

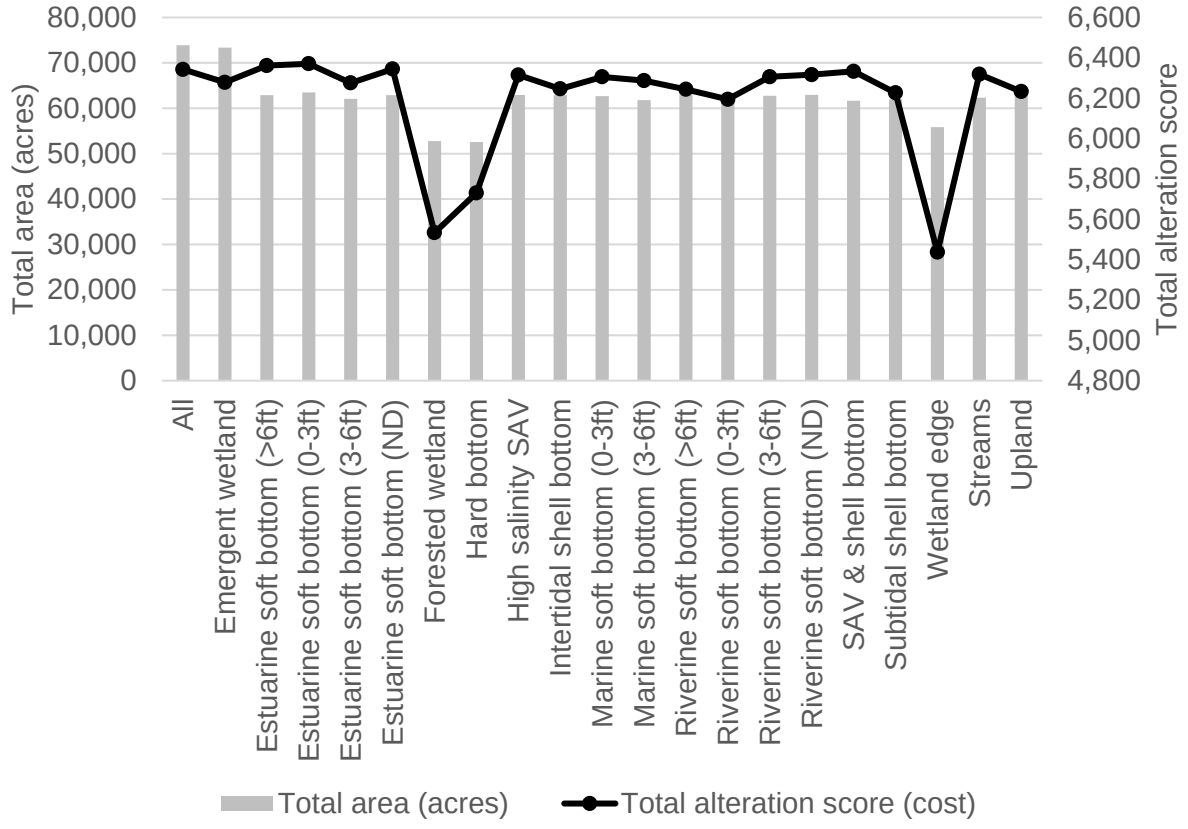


Figure 1. Natural resource target (NRT) sensitivity analysis examining the effect of excluding NRTs from the model on total area (acres) and total alteration score.

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

inlets. Thus, these areas were added in during the corroboration phase.

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

3 MARXAN RESULTS

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

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

Map 4. Marxan best solution for Region 4.

Map 5. Marxan selection frequency for Region 4.

4 CORROBORATION

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

Criteria to base modifications on included:

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

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

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

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

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

4.1 Post-Corroboration Results

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

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

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

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

Habitat type	Natural resource target	Focus area (acres)	Rep. level (%)	Target area (acres)	Percent of target (%)
Hard bottom	Hard Bottom	3,689	0	2,856	77.4
SAV	High salinity SAV	653	60	521	79.8
Shell bottom	Intertidal shell bottom	3,708	60	2,517	67.9
	Subtidal shell bottom	2,395	60	1,570	65.5
SAV & shell bottom	SAV & shell bottom	130	80	113	86.8
Creeks & Rivers	Riverine soft bottom (0-3ft)	1,902	30	386	20.3
	Riverine soft bottom (3-6ft)	292	20	43	14.8
	Riverine soft bottom (>6ft)	1,174	20	103	8.8
	Riverine soft bottom (ND)	6,764	10	2,660	39.3
Shallow soft bottom	Palustrine soft bottom (0-3ft)	18	0	0	0.0
	Palustrine soft bottom (ND)	195	0	13	6.6
	Estuarine soft bottom (0-3ft)	18,430	20	5,768	31.3
	Estuarine soft bottom (3-6ft)	3,507	20	701	20.0
	Estuarine soft bottom (ND)	6,965	0	4,243	60.9
	Marine soft bottom (0-3ft)	4,226	30	846	20.0
	Marine soft bottom (3-6ft)	3,576	20	432	12.1
	Marine soft bottom (ND)	54	0	38	71.1
Deep soft bottom	Estuarine soft bottom (>6ft)	6,911	10	699	10.1
	Marine soft bottom (>6ft)	176,471	0	4,953	2.8
Wetland	Emergent wetland	34,629	10	15,733	45.4
	Forested wetland	58,637	30	23,136	39.5
	Shrub & scrub wetland	3,792	0	916	24.2
	Wetland edge	9,067	40	5,507	60.7
Low-elevation upland	Low-elevation upland	2,110	0	470	22.3
Water column	Streams (low elevation)	624	20	226	36.2
Total Area (of mapped NRTS)		349,918		74,451	21.3
Total Area (including unmapped areas)		494,153		88,354	17.9

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

Habitat Type	Natural Resource Target	Strategic Habitat Area ID										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Hard bottom	Hard bottom	0	1	0	0	0	582	105	0	0	0	0
SAV	High salinity SAV	0	0	0	1	0	0	0	1	0	0	258
Shell bottom	Intertidal shell bottom	155	141	2	196	0	0	0	45	0	0	0
	Subtidal shell bottom	142	74	0	127	0	0	0	1	0	0	0
SAV & shell bottom	SAV & shell bottom	0	1	0	4	0	0	0	0	0	0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	0	0	8	0	0	0	0	0	0
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	227	314	18	467	0	0	0	201	18	0	1,681
	Estuarine soft bottom (3-6ft)	15	11	4	2	0	0	0	20	118	0	176
	Estuarine soft bottom (ND)	96	51	4	63	0	0	0	32	0	0	662
	Marine soft bottom (0-3ft)	73	107	0	61	0	0	0	0	76	218	17
	Marine soft bottom (3-6ft)	7	0	0	39	0	0	0	0	67	213	7
	Marine soft bottom (ND)	0	14	0	0	0	0	0	0	0	0	0
Deep soft bottom	Estuarine soft bottom (>6ft)	18	26	5	16	0	0	0	9	172	0	13
	Marine soft bottom (>6ft)	12	0	0	17	0	193	187	0	97	2,618	10
Wetland	Emergent wetland	1,521	378	72	465	0	0	0	718	0	0	3,339
	Forested wetland	1	0	0	5	289	0	0	0	0	0	41
	Shrub & scrub wetland	59	5	0	2	0	0	0	1	0	0	57
Wetland shoreline	Wetland edge	230	99	6	94	25	0	0	103	0	0	541
Low-elevation upland	Low-elevation upland	16	27	0	25	1	0	0	4	2	1	54
Water column	Streams (low elevation)	7	1	0	2	6	0	0	4	0	0	7
Total Area (of mapped NRTS)		2,579	1,250	111	1,586	329	775	292	1,139	550	3,050	6,863
Total Area (including unmapped areas)		2,579	1,593	195	2,015	500	776	292	1,139	585	3,067	7,215

Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID										
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Hard bottom	Hard bottom	39	0	0	46	72	383	0	65	1,203	0	2
SAV	High salinity SAV	0	0	0	0	0	0	37	0	0	3	221
Shell bottom	Intertidal shell bottom	0	0	4	0	0	0	413	0	0	291	1,269
	Subtidal shell bottom	0	0	479	0	0	0	211	0	0	34	501
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	14	0	0	1	93
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	191	0	0	0	610	0	0	337	1,671
	Estuarine soft bottom (3-6ft)	0	0	0	0	0	0	109	0	0	23	170
	Estuarine soft bottom (ND)	0	0	4	0	0	0	1,237	0	0	335	1,575
	Marine soft bottom (0-3ft)	0	0	0	21	0	0	46	0	0	2	224
	Marine soft bottom (3-6ft)	0	0	0	19	0	0	1	0	0	2	78
	Marine soft bottom (ND)	0	0	0	0	0	0	4	0	0	3	17
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	0	0	150	0	0	23	112
	Marine soft bottom (>6ft)	156	98	0	208	91	234	0	32	492	13	71
Wetland	Emergent wetland	0	0	66	0	0	0	2,004	0	0	911	3,849
	Forested wetland	0	0	0	0	0	0	55	0	0	12	70
	Shrub & scrub wetland	0	0	1	0	0	0	47	0	0	21	58
Wetland shoreline	Wetland edge	0	0	10	0	0	0	652	0	0	397	1,676
Low-elevation upland	Low-elevation upland	0	0	0	11	0	0	74	0	0	31	52
Water column	Streams (low elevation)	0	0	0	0	0	0	4	0	0	2	2
Total Area (of mapped NRTS)		195	98	755	305	163	617	5,668	97	1,695	2,441	11,711
Total Area (including unmapped areas)		195	98	755	358	163	617	6,175	98	1,710	2,665	11,711

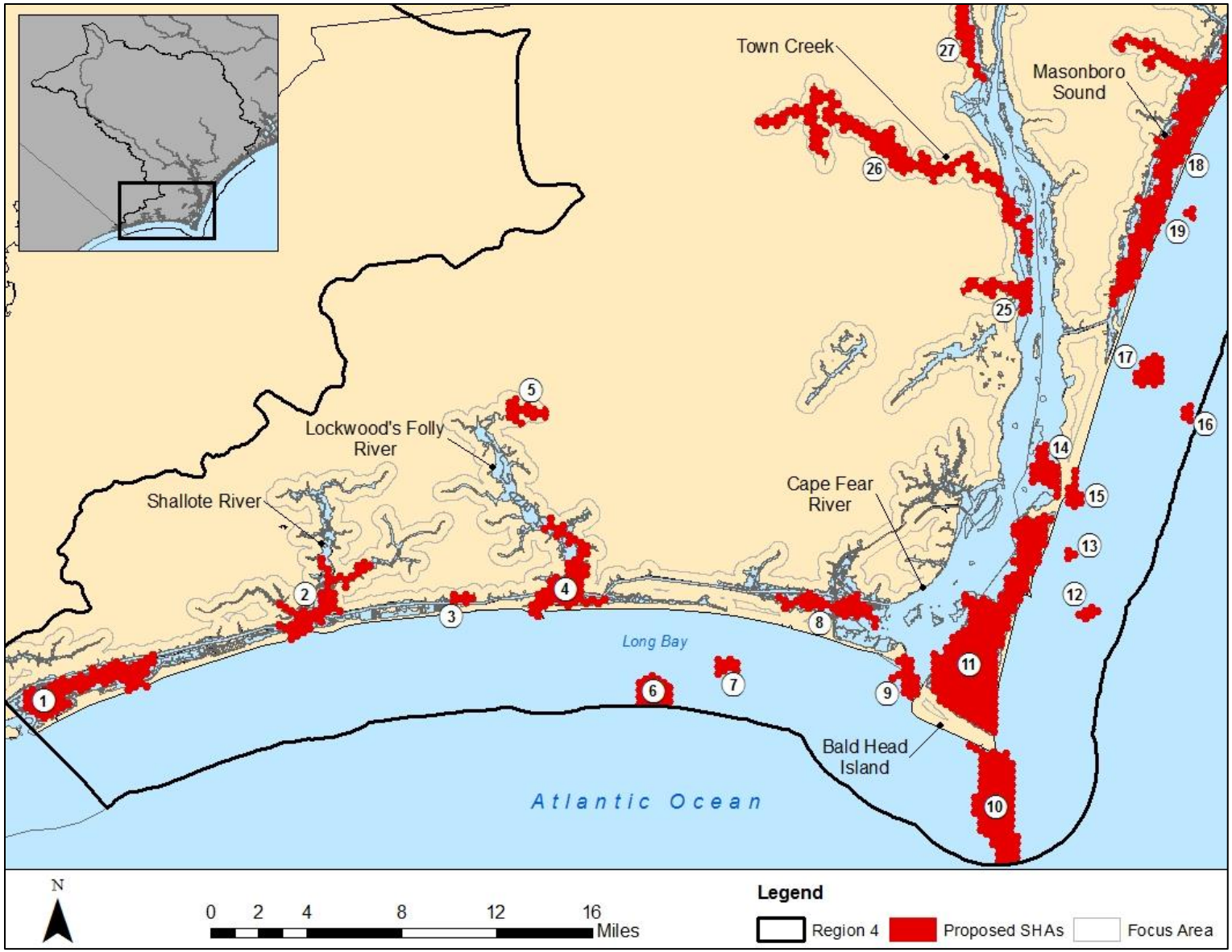
Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID										
		23	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Hard bottom	Hard bottom	105	250	0	0	0	0	0	0	0	0	0
SAV	High salinity SAV	0	0	0	0	0	0	0	0	0	0	0
Shell bottom	Intertidal shell bottom	0	0	0	0	0	0	0	0	0	0	0
	Subtidal shell bottom	0	0	0	0	0	0	0	0	0	0	0
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	0	0	0	0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	121	265	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	14	29	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	30	73	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	0	0	23	207	1	15	40	58	274	69	372
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	0	3	30	0	0	0	0	0	0
	Estuarine soft bottom (3-6ft)	0	0	0	0	51	0	0	0	0	0	0
	Estuarine soft bottom (ND)	0	0	0	50	115	18	0	0	0	0	0
	Marine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0	0
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	154	0	0	0	0	0	0
	Marine soft bottom (>6ft)	0	302	0	0	0	0	0	0	0	0	0
Wetland	Emergent wetland	122	0	330	753	648	377	2	9	19	0	186
	Forested wetland	0	0	65	1,469	19	8	276	581	2,422	341	1,627
	Shrub & scrub wetland	0	0	74	268	32	0	11	0	5	0	19
Wetland shoreline	Wetland edge	0	0	56	268	63	63	29	27	168	27	129
Low-elevation upland	Low-elevation upland	0	0	2	27	9	3	0	1	2	0	6
Water column	Streams (low elevation)	0	0	6	39	2	4	5	2	14	2	6
Total Area (of mapped NRTS)			552	721	3,451	1,124	488	363	678	2,904	439	2,345
Total Area (including unmapped areas)		227	553	843	4,210	1,331	488	406	811	3,332	439	2,718

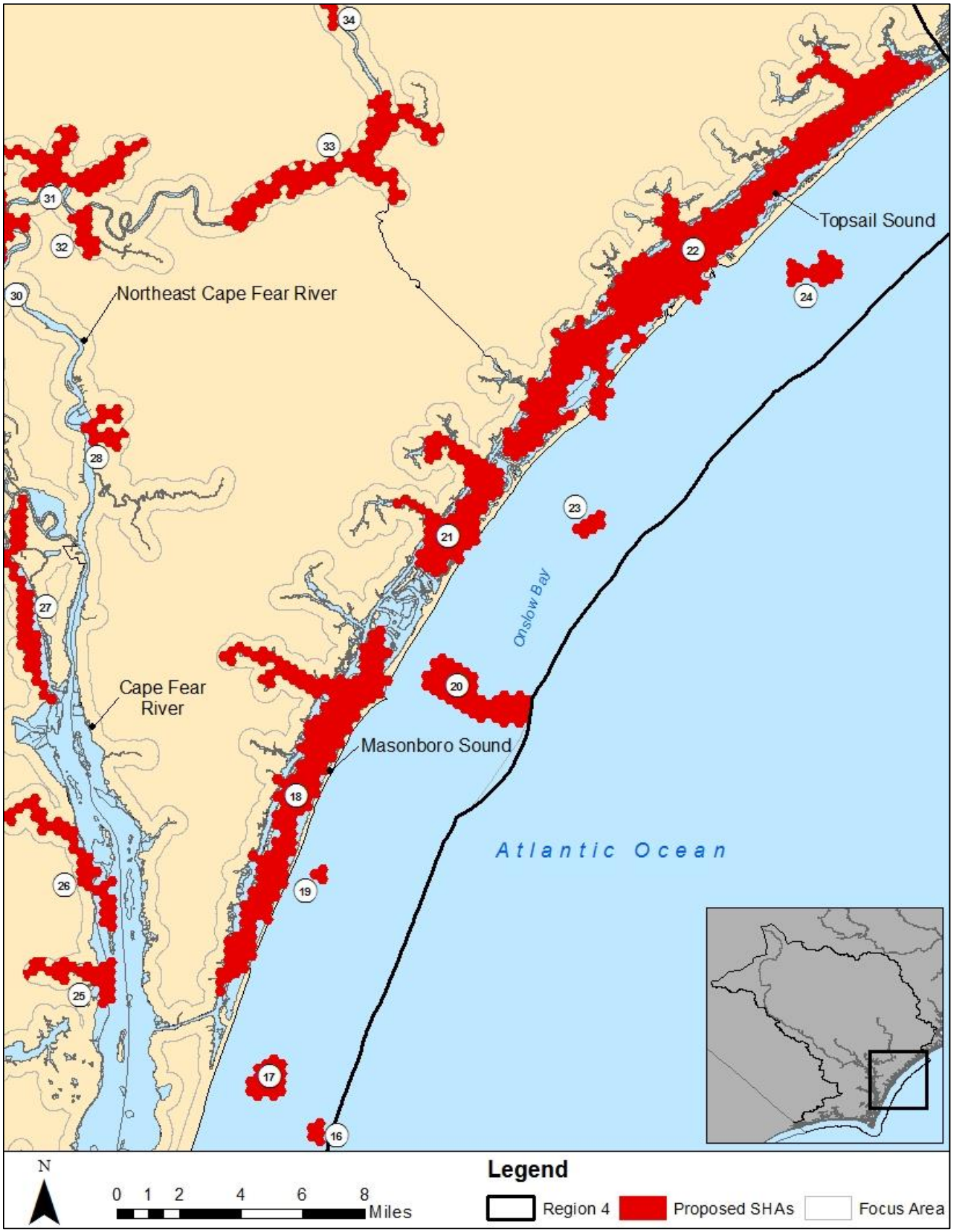
Table 7. Continued.

Habitat Type	Natural Resource Target	Strategic Habitat Area ID									
		34	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
Hard bottom	Hard bottom	0	0	0	0	0	0	0	0	0	0
SAV	High salinity SAV	0	0	0	0	0	0	0	0	0	0
Shell bottom	Intertidal shell bottom	0	0	0	0	0	0	0	0	0	0
	Subtidal shell bottom	0	0	0	0	0	0	0	0	0	0
SAV & shell bottom	SAV & shell bottom	0	0	0	0	0	0	0	0	0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0
	Riverine soft bottom (ND)	234	68	88	36	173	0	20	0	0	519
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0	0	0	0	0	455	0	0	0	0
	Palustrine soft bottom (ND)	0	0	0	0	0	13	0	0	0	0
	Estuarine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0
	Estuarine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (0-3ft)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (3-6ft)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (ND)	0	0	0	0	0	0	0	0	0	0
Deep soft bottom	Estuarine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0
	Marine soft bottom (>6ft)	0	0	0	0	0	0	0	0	0	0
Wetland	Emergent wetland	0	0	13	0	0	11	7	17	36	3
	Forested wetland	1,340	787	515	493	2,026	3,853	2,621	2,206	1,533	472
	Shrub & scrub wetland	1	2	0	0	0	0	25	132	104	0
Wetland shoreline	Wetland edge	147	88	57	59	119	370	0	0	0	0
Low-elevation upland	Low-elevation upland	16	4	53	11	2	37	0	0	0	0
Water column	Streams (low elevation)	2	11	13	9	6	43	7	6	6	8
Total Area (of mapped NRTS)		1,740	960	739	608	2,326	4,782	2,680	2,361	1,679	1,002
Total Area (including unmapped areas)		2,096	1,179	1,427	839	2,326	5,938	3,832	3,601	4,370	2,887

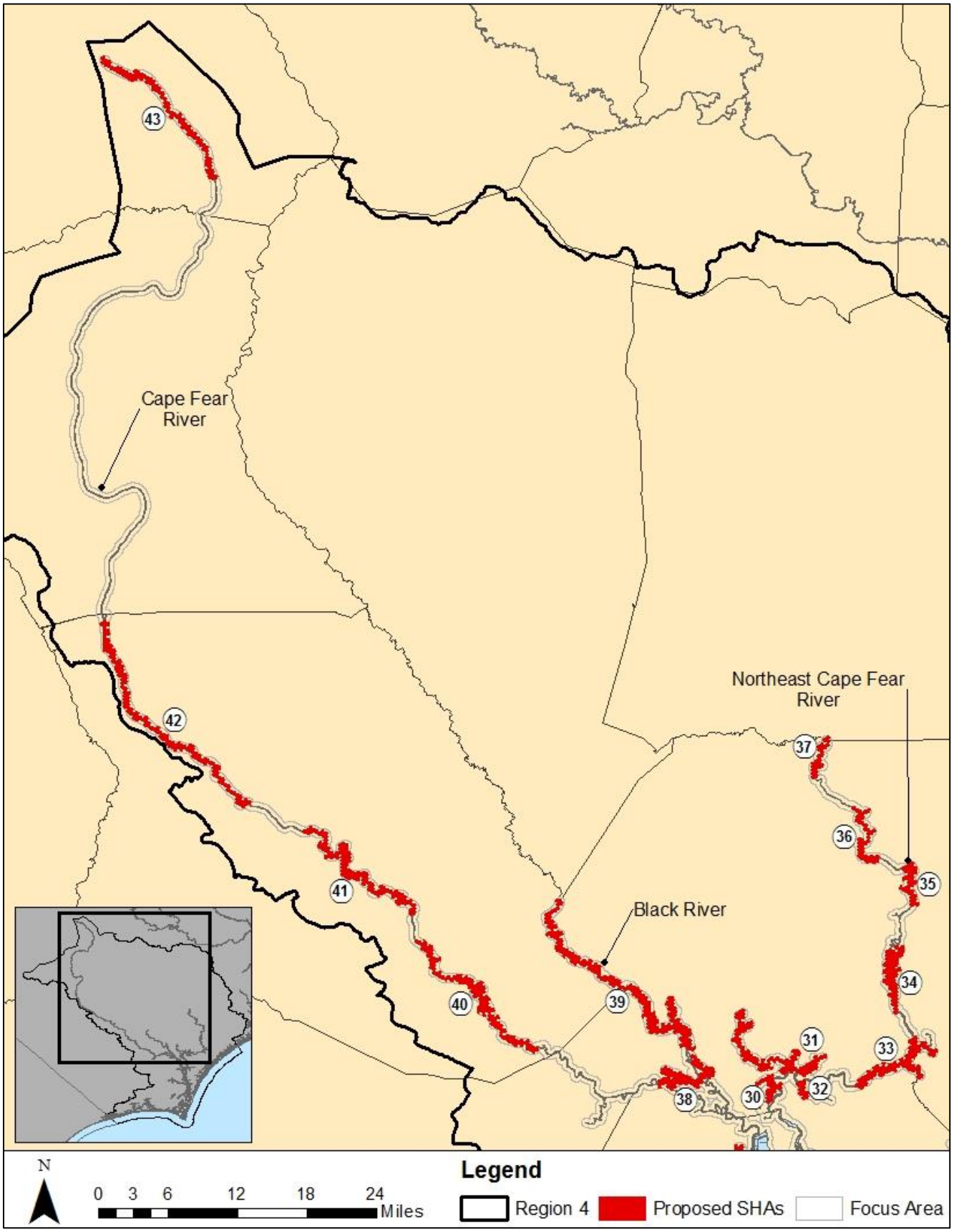
Map 6a. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration.



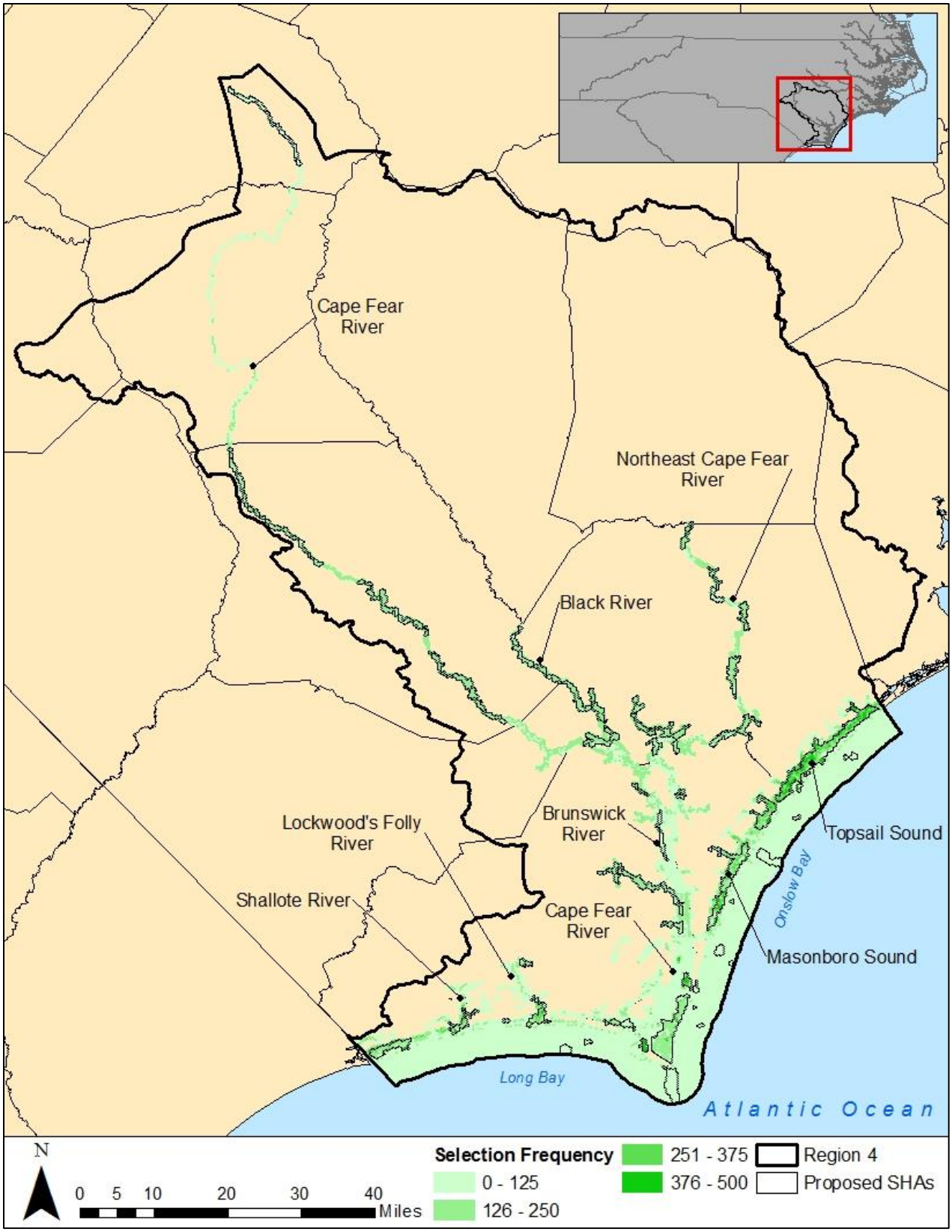
Map 6b. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration, #1-19 and 25-27.



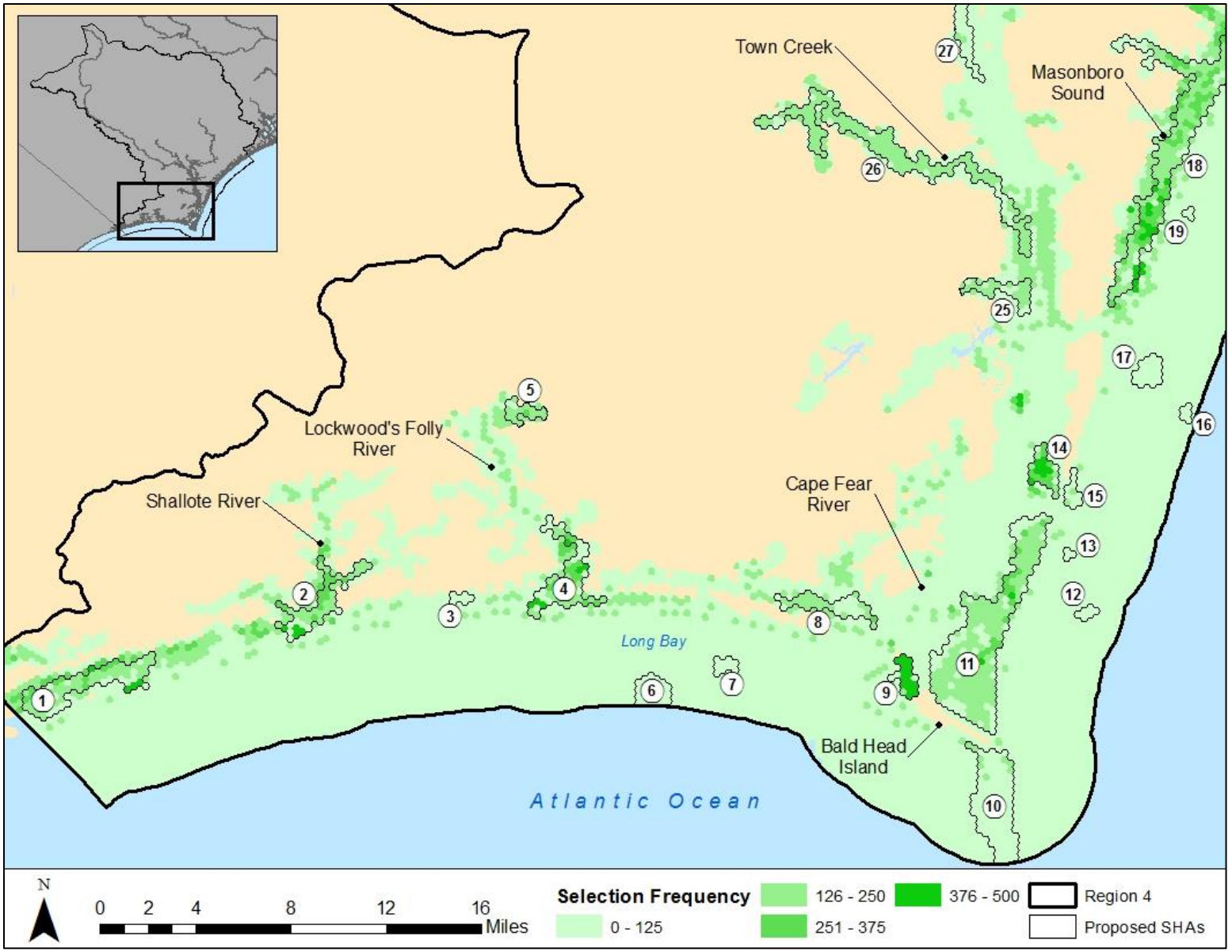
Map 6c. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration, #16-34 and 38-39.



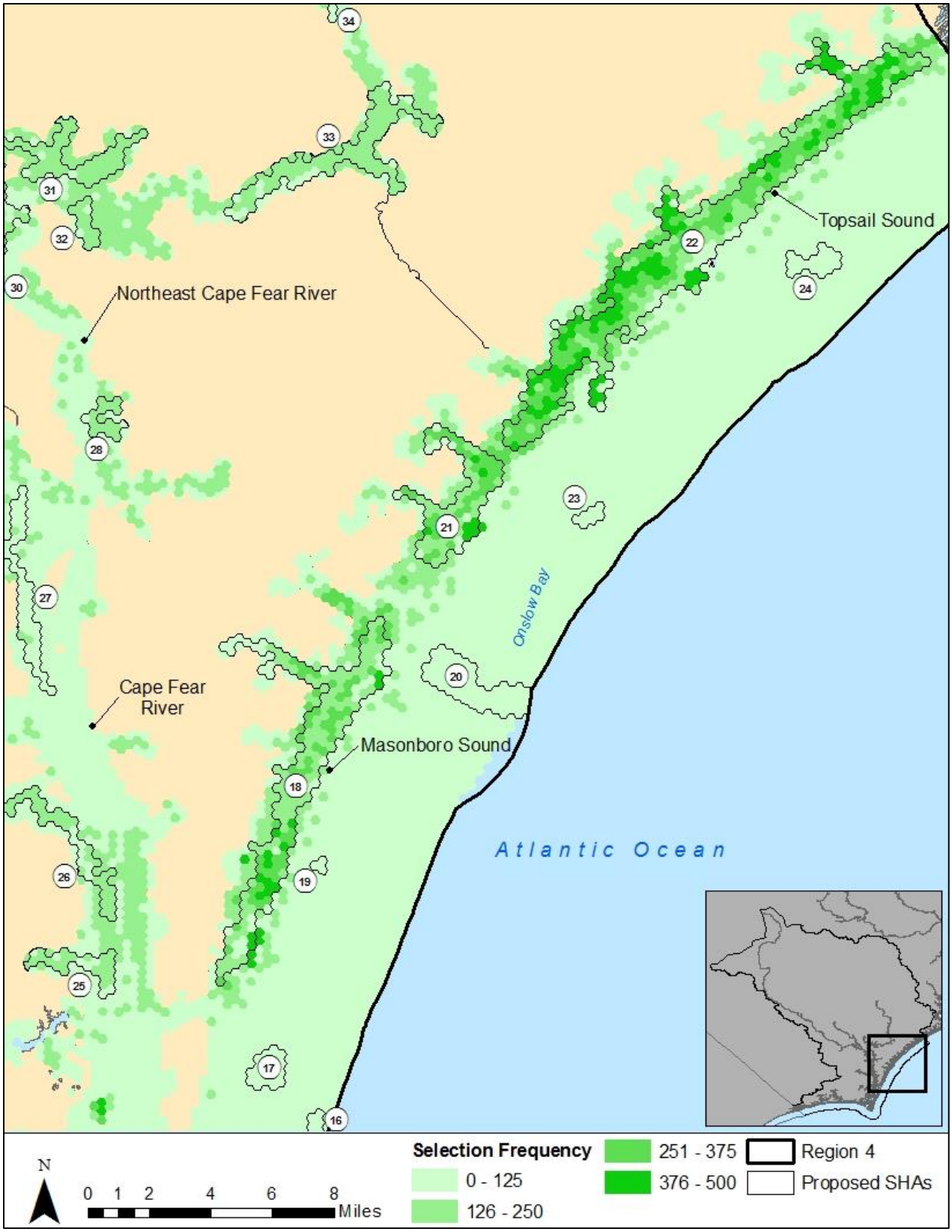
Map 6d. Region 4 Strategic Habitat Area (SHA) Nominations post-corroboration., #30-43.



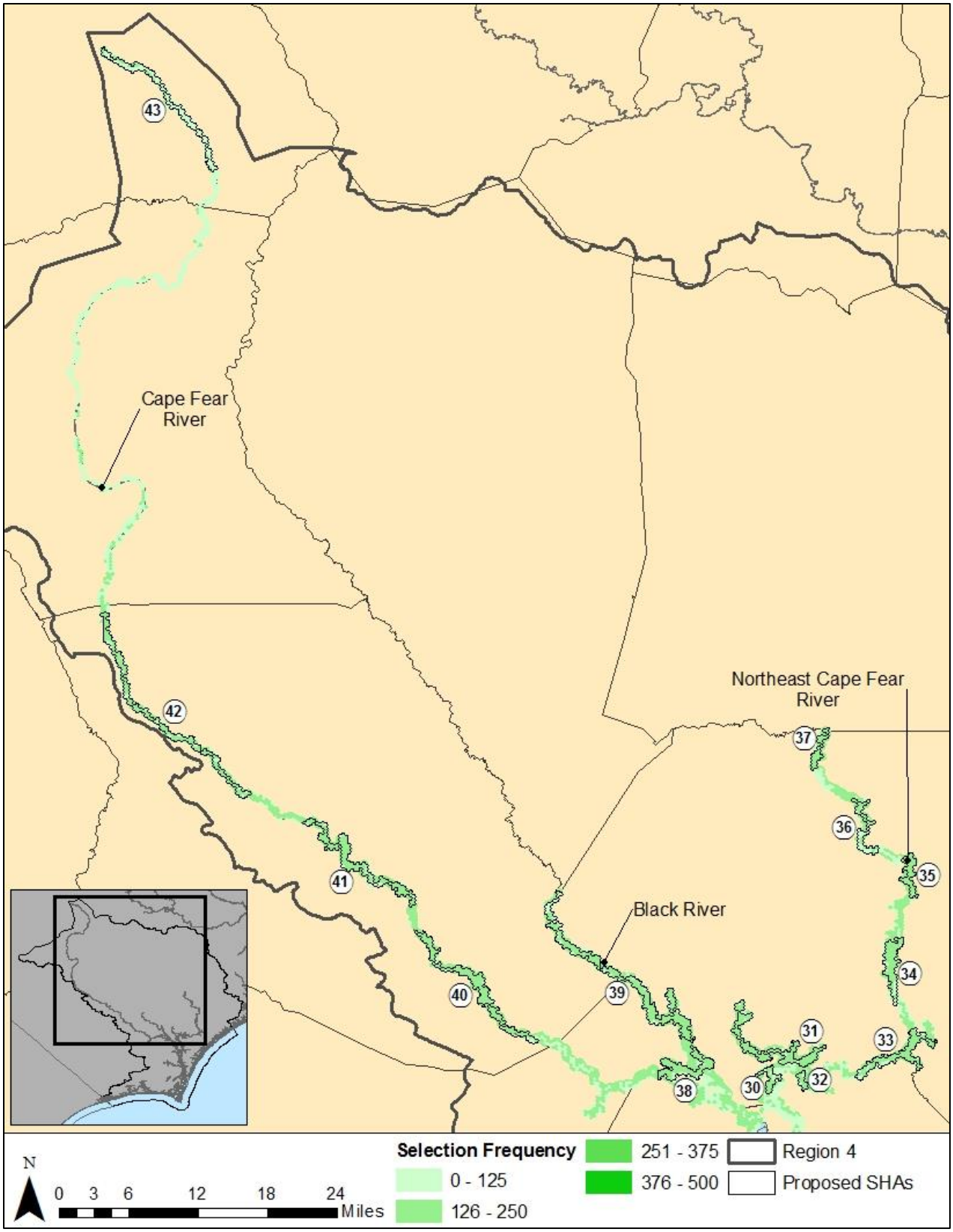
Map 7a. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration.



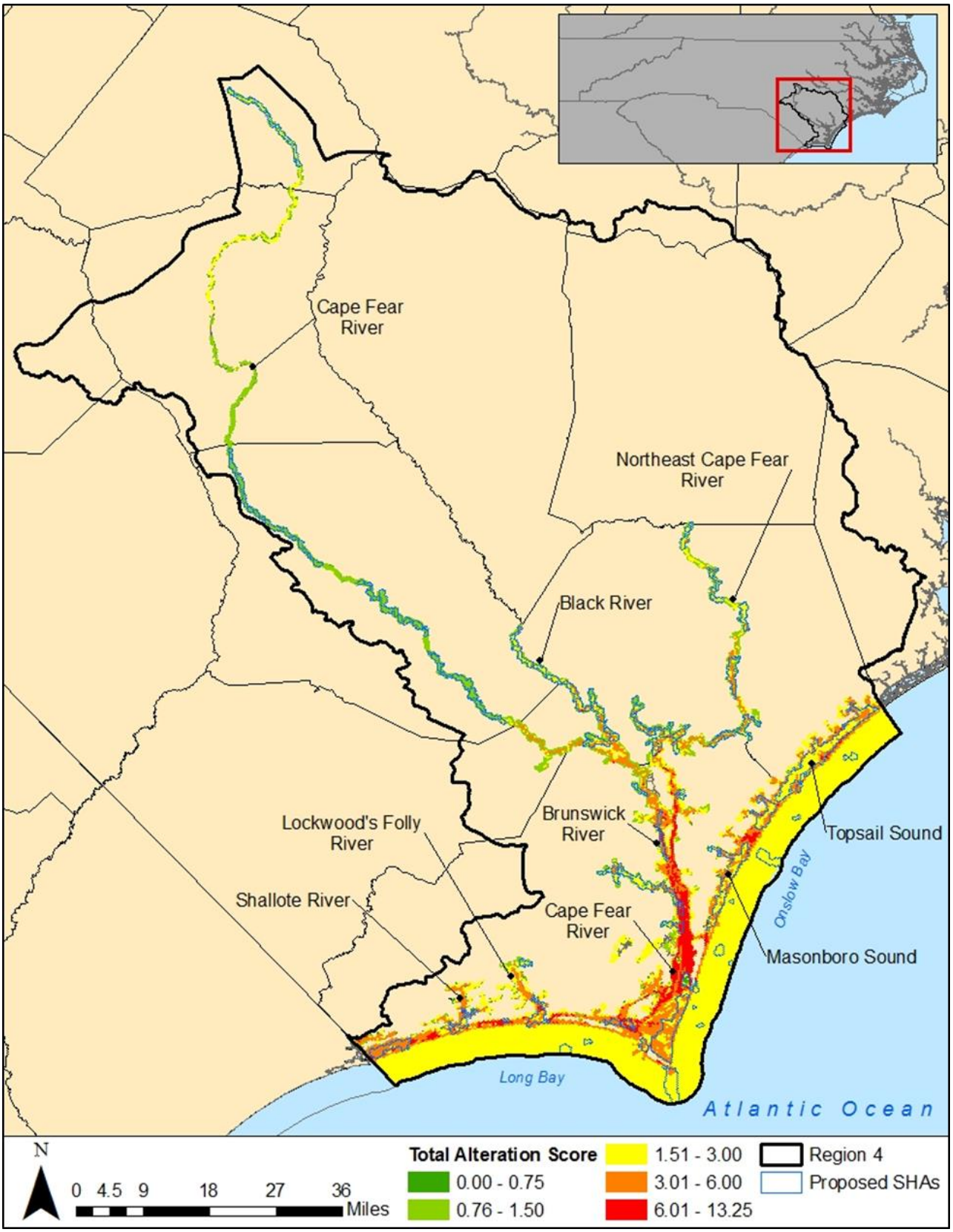
Map 7b. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #1-18 and 25-27.



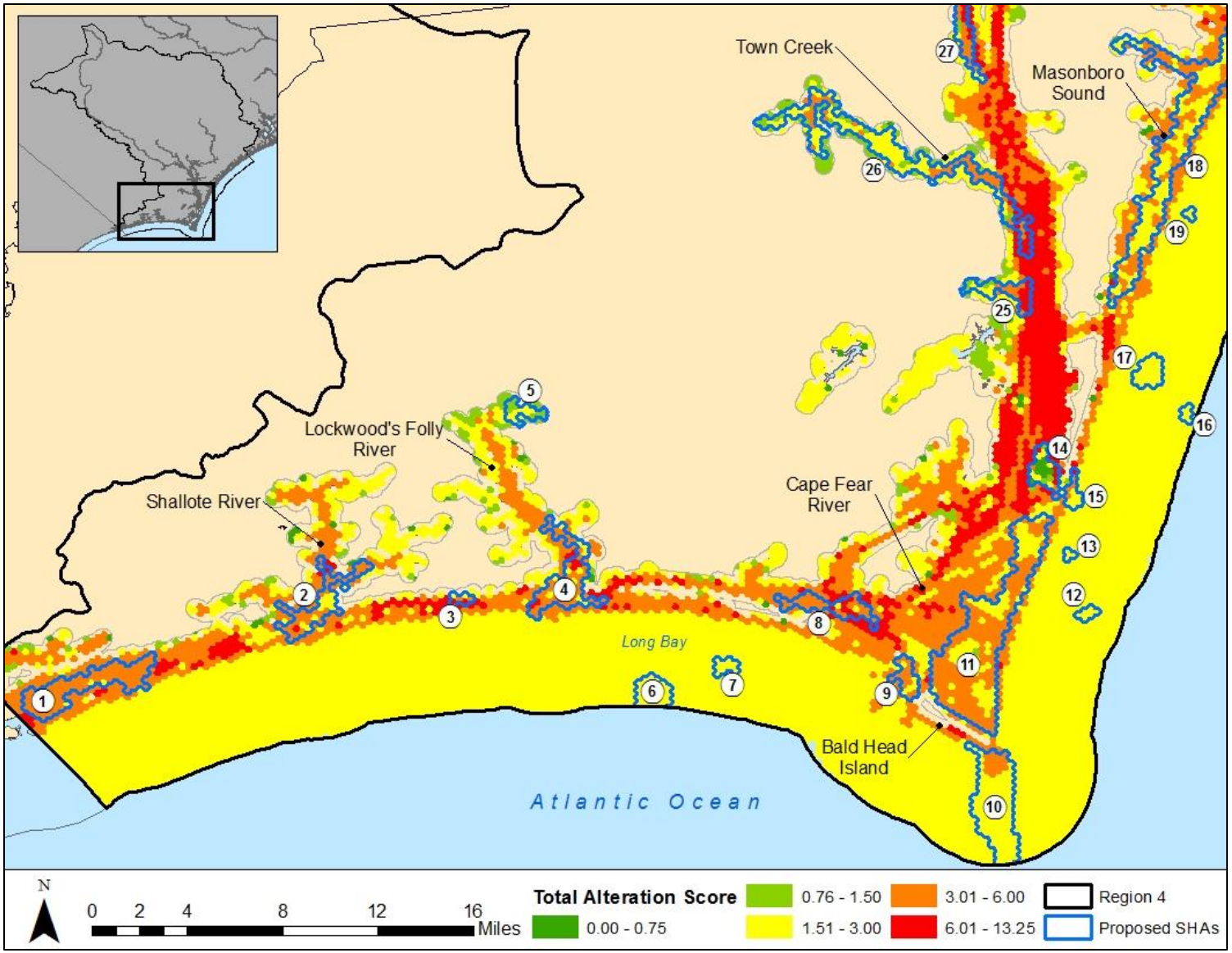
Map 7c. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #16-28 and 30-34.



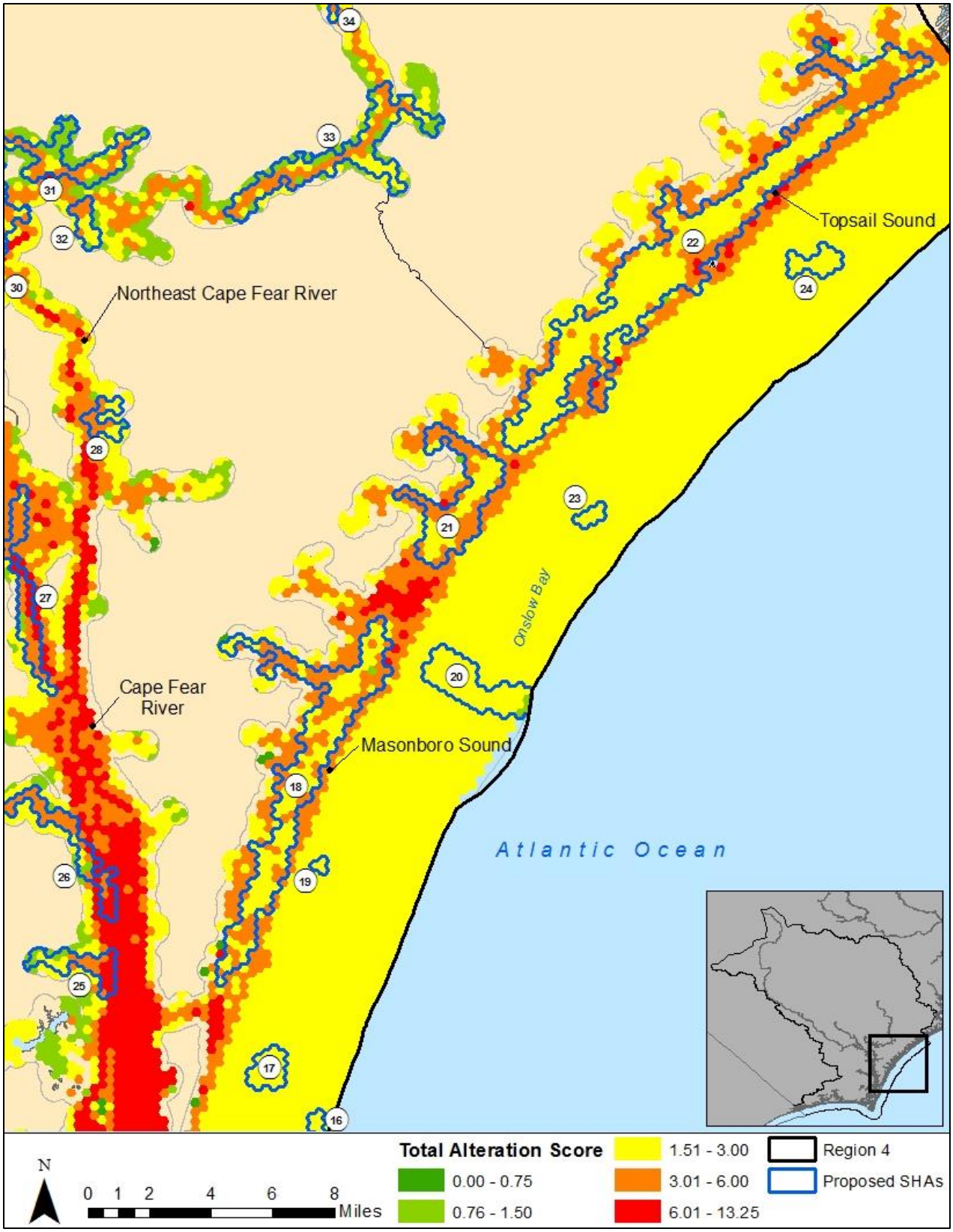
Map 7d. Selection frequencies of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration, #30-43.



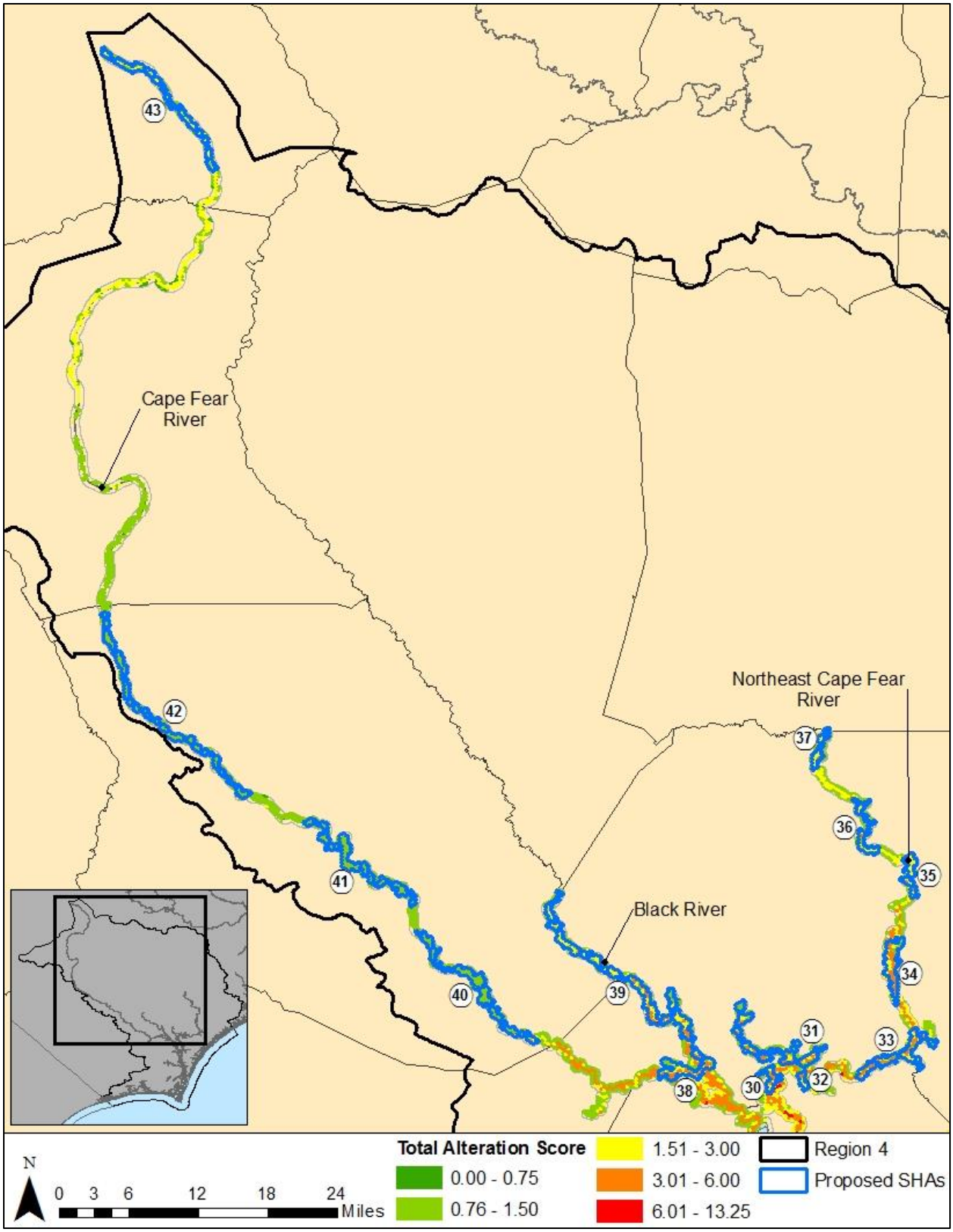
Map 8a. Alteration scores of Region 4 Strategic Habitat Area (SHA) nominations post-corroboration.



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



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



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

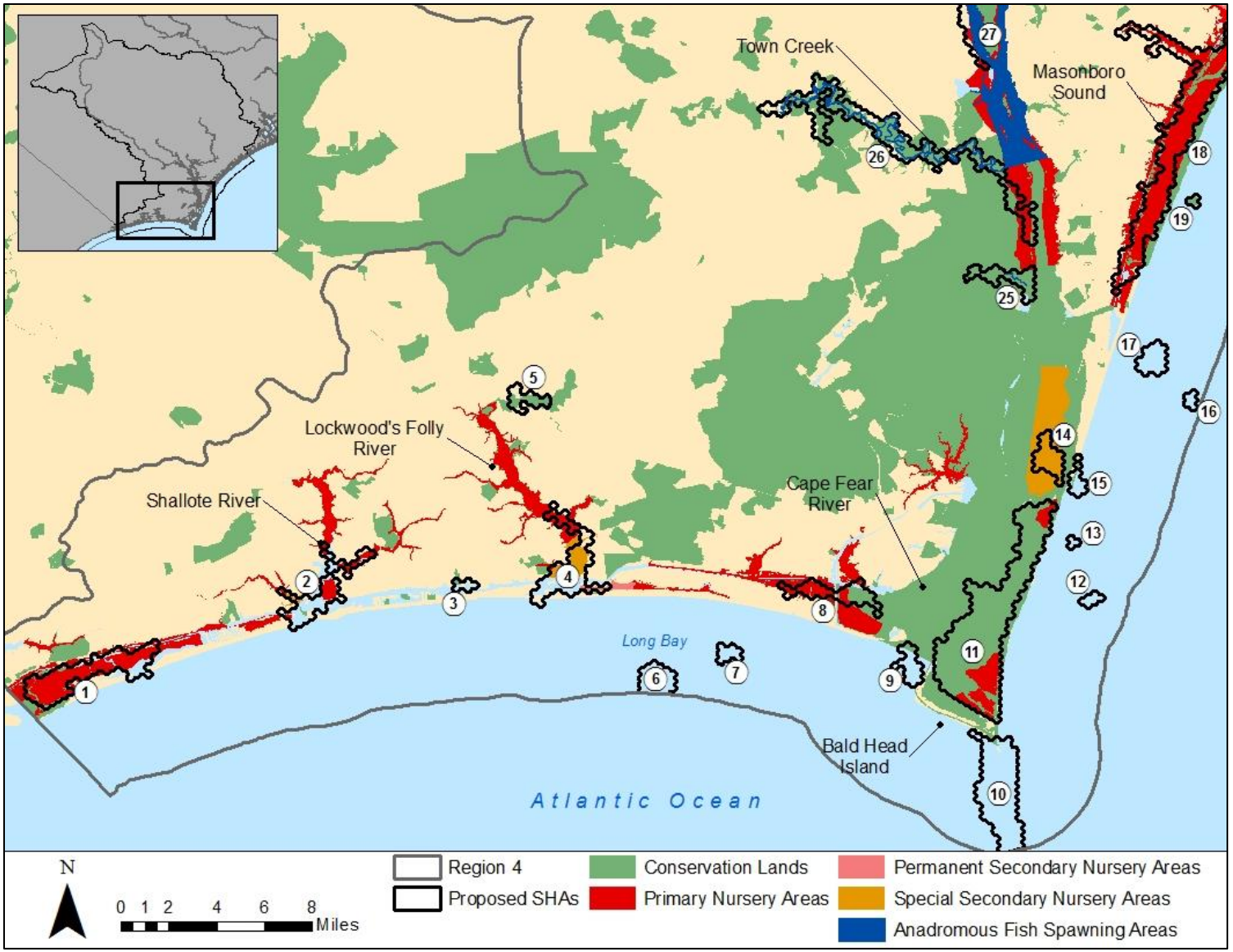
The final SHA selections form a network of priority areas for protection and enhancement ranging from the headwaters of the Cape Fear River to the seagrass beds and marshes of the sounds and inlets. Selections were scattered throughout the area and concentrated in the sounds, tidal creeks, and river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

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

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

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

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



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

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

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

5 FINAL STRATEGIC HABITAT AREA NOMINATIONS

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

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

Water quality classifications include:

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

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

5.1 Brunswick County Waters

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

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

SHA #2 (Map 11)	Shallotte Inlet
Description	Shallotte Inlet, mouth of Shallotte River, and Saucepan and Shallotte creeks
Acres	1,593
Prominent Habitats	Emergent wetland, estuarine soft bottom (0-3ft), and intertidal shell bottom
Ecological Designations	PNA and SSNA
Conservation Lands	North Carolina Agricultural Foundation Preserve
Water Quality Ratings	Mostly impaired (Cat 4&5) and some supporting
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marinas, trawling, and drained
Average Total Alteration Score	3.49
Average Selection Frequency	216

SHA #3 (Map 12)	Holden Beach
Description	West of bridge at Holden Beach
Acres	195
Prominent Habitats	Emergent wetlands
Ecological Designations	None
Conservation Lands	Succession maritime forest
Water Quality Ratings	Impaired (Cat 5)
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	4.99
Average Selection Frequency	69

SHA #4 (Map 12)	Lockwoods Folly Inlet and River
Description	Lockwoods Folly Inlet, mouth of Lockwoods Folly River to Rourks Landing and Montgomery Slough
Acres	2,015
Prominent Habitats	Emergent wetlands and estuarine soft bottom (0-3ft)
Ecological Designations	PSNA, SSNA, and PNA
Conservation Lands	Stanly Road Coastal Fringe Forest and Lockwoods Folly River Tidal Wetlands
Water Quality Ratings	Mostly impaired (Cat 4 & 5) and some supporting
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marina, trawling, and drained
Average Total Alteration Score	4.05
Average Selection Frequency	206

SHA #5 (Map 13)	Lockwoods Folly River
Description	Lockwoods Folly River northeast of Supply
Acres	500
Prominent Habitats	Forested wetland
Ecological Designations	PSNA and SSNA
Conservation Lands	Lockwoods Folly River Tidal Wetlands
Water Quality Ratings	Some supporting
Water Quality Classifications	SA and HQW
Fish Data	None
Prominent Alterations	Major NPDES
Average Total Alteration Score	1.56
Average Selection Frequency	170

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

SHA #7 (Map 14)	Yaupon Beach Reef – Artificial Reef 425
Description	6.3 nm from Lockwoods Folly Inlet, 3.8 nm from Oak Island Light, and 7.4 nm from Cape Fear River sea buoy
Acres	292
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Trawling and major NPDES
Average Total Alteration Score	2.00
Average Selection Frequency	None

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

SHA #9 (Maps 15 and 17)	Cape Fear River Inlet
Description	Cape Fear River Inlet
Acres	585
Prominent Habitats	Estuarine and marine soft bottom (>6ft)
Ecological Designations	PNA
Conservation Lands	Portions of Bald Head Island, Fort Caswell Dunes and Marshes, and Lower Cape Fear River Aquatic Habitat
Water Quality Ratings	Some supporting
Water Quality Classifications	SA and HQW
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	3.59
Average Selection Frequency	411

SHA #10 (Map 16)	Frying Pan Shoal
Description	Frying Pan shoal off Bald Head Island
Acres	3,067
Prominent Habitats	Marine soft bottom (>6ft)
Ecological Designations	Essential Fish Habitat and Habitat of Particular Concern
Conservation Lands	Bald Head Island
Water Quality Ratings	Some supporting
Water Quality Classifications	SA and HQW
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.33
Average Selection Frequency	None

SHA #11 (Maps 16 and 17)	Bald Head Island
Description	Bald Head Island to Fort Fisher State Recreation Area
Acres	7,215
Prominent Habitats	Emergent wetland and estuarine soft bottom (0-3ft)
Ecological Designations	TNPA and PNA
Conservation Lands	Bald Head Island State Natural Area, Zeke's Island Estuarine Sanctuary, Fort Fisher State Recreation Area, and Military Ocean Terminal Sunny Point
Water Quality Ratings	Mostly supporting and some impaired (Cat 5)
Water Quality Classifications	SA and HQW
Fish Data	DMF Programs 120, 510, and 915
Prominent Alterations	Major NPDES, drainage, trawling, and minor NPDES
Average Total Alteration Score	3.19
Average Selection Frequency	163

5.2 New Hanover and Pender County Waters

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

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

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

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

SHA #15 (Map 18)	Fort Fisher Cocquina Outcrop
Description	Fort Fisher Cocquina outcrop
Acres	358
Prominent Habitats	Marine soft bottom (>6ft) and hard bottom
Ecological Designations	None
Conservation Lands	MOTSU buffer zone natural area, Fort Fisher Cocquina outcrop, and Fort Fisher State Historic Site
Water Quality Ratings	Some Supporting
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	3.12
Average Selection Frequency	None

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

SHA #17 (Map 18)	Phillip Wolfe Reef – Artificial Reef 378
Description	3.2 nm from Carolina Beach Inlet buoy
Acres	617
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

SHA #18 (Map 19)	Masonboro Island
Description	Masonboro Island including Hewletts Creek
Acres	6,175
Prominent Habitats	Emergent wetland and estuarine soft bottom (0-3ft) and (ND)
Ecological Designations	PNA
Conservation Lands	Masonboro Island National Estuarine Research Reserve, Masonboro Island State Natural Area, and New Hanover Conservation Lands
Water Quality Ratings	Some supporting and some impaired (Cat 5)
Water Quality Classifications	SA, HQW, and ORW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Marinas and major NPDES
Average Total Alteration Score	3.11
Average Selection Frequency	221

SHA #19 (Map 19)	Masonboro Outcrop
Description	3.6 nm from the Carolina Beach Inlet buoy
Acres	98
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	Masonboro outcrop
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.02
Average Selection Frequency	None

SHA #20 (Map 19)	Meares Harris – Artificial Reef 370
Description	2.3 nm from Masonboro Inlet sea buoy
Acres	1,710
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	1.93
Average Selection Frequency	None

SHA #21 (Map 20)	North Wrightsville Beach
Description	Howe and Pages creeks, and connecting ICW
Acres	2,665
Prominent Habitats	Emergent wetlands, wetland edge, and estuarine soft bottom(0-3ft and ND)
Ecological Designations	PNA, PSNA, and TNPA
Conservation Lands	Howe and Pages creeks natural areas and Figure Eight Island marsh
Water Quality Ratings	Some supporting and some impaired (Cat 5)
Water Quality Classifications	SA, ORW, and HQW
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, marina, trawling, drained, and development
Average Total Alteration Score	3.28
Average Selection Frequency	251

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

SHA #23 (Map 20)	Billy Murrel Reef – Artificial Reef 364
Description	6.1 nm from Masonboro Inlet sea buoy and 6.5 nm from New Topsail Inlet sea buoy
Acres	227
Prominent Habitats	Hard bottom and marine soft bottom (>6ft)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	None
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and trawling
Average Total Alteration Score	2.00
Average Selection Frequency	None

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

5.3 Cape Fear River

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

SHA #25 (Map 22)	Cape Fear River – Lilliput Creek
Description	Lilliput Creek just north of Sunny point military terminal
Acres	843
Prominent Habitats	Emergent wetlands and riverine soft bottom (0-3ft)
Ecological Designations	PNA and AFSA
Conservation Lands	Blue Pond/Allen Creek, Orton Sandhills and Limesinks, and Lower Cape Fear River Aquatic Habitat
Water Quality Ratings	Mostly no data and some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	DMF Programs 510 and 915
Prominent Alterations	Major NPDES and drained
Average Total Alteration Score	4.41
Average Selection Frequency	149

SHA #26 (Map 22)	Cape Fear River – Town Creek
Description	Town Creek including western portion of Cape Fear River to Sand Hill Creek
Acres	4,210
Prominent Habitats	Forested wetland and emergent wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Lower Cape Fear River aquatic habitat, Pleasant Oaks/ Goose Landing Plantations, Town Creek marshes and swamp, North Carolina Coastal Land Trust Easement, Brunswick County Open Space, and North Carolina Clean Water Management Trust Fund Easement
Water Quality Ratings	Mostly no data and some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	DMF Programs 120, 510, and 915 and WRC annual spawning stock survey
Prominent Alterations	Major NPDES and drained
Average Total Alteration Score	3.05
Average Selection Frequency	155

SHA #29 (Map 24)	Cape Fear River – Indian Creek
Description	Cape Fear River at mouth of Indian Creek to convergence of Otter Branch and Mulberry Branch
Acres	406
Prominent Habitats	Forested wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	None
Water Quality Ratings	Mostly no data and some supporting
Water Quality Classifications	None
Fish Data	DMF Program 120 and WRC IBI sampling
Prominent Alterations	Major NPDES
Average Total Alteration Score	2.37
Average Selection Frequency	182

SHA #38 (Map 29)	Cape Fear River Lowlands
Description	Cape Fear River including Lyon creek, Crossway Creek and Lyon Thorofare
Acres	2,326
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Lower Black River Swamp and Cape Fear River Wetlands Game Land
Water Quality Ratings	Mostly no data and some supporting
Water Quality Classifications	None
Fish Data	DMF Program 120 and WRC IBI sampling
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	2.40
Average Selection Frequency	160

SHA #40 (Map 31)	Cape Fear River – Kelly
Description	Cape Fear River near Beaverdam Creek and Kelly
Acres	3,832
Prominent Habitats	Forested wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	Cape Fear River Lowlands, Steep Run Swamp, Cape Fear River Kelly Bottomlands, Cape Fear River/ Whitehall Floodplain Forest, North Carolina Coastal Land Trust Easement, Whitehall Plantation Game Land, and Bladen Lakes State Forest
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	WRC IBI sampling and annual spawning stock survey
Prominent Alterations	Major NPDES
Average Total Alteration Score	1.04
Average Selection Frequency	165

SHA #41 (Map 32)	Cape Fear River – Elizabethtown
Description	Cape Fear River including Pemberton Creek and mouth of Mulford Creek
Acres	3,601
Prominent Habitats	Forested wetlands
Ecological Designations	AFSA
Conservation Lands	Cape Fear Sloughs, Walkers Bluff, and Sugar Loaf Springs
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	WRC IBI sampling
Prominent Alterations	Major NPDES
Average Total Alteration Score	0.98
Average Selection Frequency	153

SHA #42 (Map 33)	Cape Fear River – Tarheel
Description	South of Fayetteville on the Cape Fear River
Acres	4,370
Prominent Habitats	Forested wetlands
Ecological Designations	AFSA,
Conservation Lands	Cape Fear River Terraces and North Carolina Coastal Land Trust Preserve
Water Quality Ratings	Mostly supporting
Water Quality Classifications	None
Fish Data	WRC IBI sampling and annual spawning stock survey
Prominent Alterations	Major NPDES
Average Total Alteration Score	1.00
Average Selection Frequency	144

SHA #43 (Map 34)	Cape Fear River – Lillington
Description	North of Fayetteville on the Cape Fear River
Acres	2,887
Prominent Habitats	Riverine soft bottom and forested wetlands
Ecological Designations	AFSA
Conservation Lands	Cape Fear River Canebrakes, Byrd Farm Industrial Park Natural Area, Upper Cape Fear River Aquatic Habitat, and Cape Fear River Park
Water Quality Ratings	Mostly impaired (Cat 5) and some supporting
Water Quality Classifications	None
Fish Data	WRC IBI sampling and annual spawning stock survey
Prominent Alterations	Major NPDES and minor NPDES
Average Total Alteration Score	1.84
Average Selection Frequency	71

5.4 Brunswick River

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

SHA #27 (Map 23)	Brunswick River
Description	Begins south of Eagle Island along western shoreline of Belville and Leland to parts of Alligator Creek and adjacent wetlands
Acres	1,331
Prominent Habitats	Emergent wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	Lower Cape Fear River Aquatic Habitat, Brunswick River/Cape Fear River Marshes, Brunswick County Open Space, and Eagles Island Natural Area
Water Quality Ratings	Mostly impaired (Cat 5) and some no data
Water Quality Classifications	SC
Fish Data	DMF Programs 120 and 510
Prominent Alterations	Major NPDES, minor NPDES, and drained
Average Total Alteration Score	4.92
Average Selection Frequency	84

5.5 Northeast Cape Fear River

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

SHA #28 (Map 24)	Northeast Cape Fear River – Ness Creek
Description	North of Wilmington near Wrightsboro and Ness creek
Acres	553
Prominent Habitats	Emergent wetlands
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain
Water Quality Ratings	Some no data and some impaired (Cat 5)
Water Quality Classifications	SC
Fish Data	None
Prominent Alterations	Major NPDES and drained
Average Total Alteration Score	3.03
Average Selection Frequency	162

SHA #30 (Map 25)	Northeast Cape Fear River – Cowpen Branch
Description	Northeast Cape Fear River including Cowpen Branch
Acres	811
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain
Water Quality Ratings	Some no data and some supporting
Water Quality Classifications	None
Fish Data	DMF Program 120
Prominent Alterations	Major NPDES
Average Total Alteration Score	2.31
Average Selection Frequency	150

SHA #31 (Map 25)	Northeast Cape Fear River – Long Creek
Description	Northeast Cape Fear River including Long, Morgans, and Turkey creeks
Acres	3,332
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River floodplain and Cape Fear River Wetlands Game Land
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	DMF Program 120
Prominent Alterations	Major NPDES, marinas, and shellfish closure
Average Total Alteration Score	2.31
Average Selection Frequency	161

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

SHA #33 (Map 26)	Northeast Cape Fear River – Castle Hayne
Description	Northeast Cape Fear River with portions of Island Creek and Harrison's Creek
Acres	2,718
Prominent Habitats	Forested wetland and riverine soft bottom (ND)
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain, Rocky Point Sandhills, North Carolina Coastal Land Trust Preserve and Easement
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	DMF Program 120
Prominent Alterations	Major NPDES, marinas, shellfish closure, and drained
Average Total Alteration Score	2.67
Average Selection Frequency	150

SHA #34 (Map 26)	Northeast Cape Fear River – Rocky Point
Description	Northeast Cape Fear River with portions of Pike, Mcintre and Lillington creeks
Acres	2,096
Prominent Habitats	Forested wetland
Ecological Designations	PNA and AFSA
Conservation Lands	Northeast Cape Fear River Floodplain and Cape Fear River Wetlands Game Land
Water Quality Ratings	Mostly supporting, some no data, and some impaired (Cat 5)
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES, marinas, and shellfish closure
Average Total Alteration Score	2.86
Average Selection Frequency	149

SHA #35 (Map 27)	Northeast Cape Fear River – Ashes Creek
Description	Northeast Cape Fear River with Ashes Creek
Acres	1,179
Prominent Habitats	Forested wetland
Ecological Designations	AFSA
Conservation Lands	Northeast Cape Fear River Floodplain, Holly Shelter Game Land, and North Carolina Coastal Land Trust Easement
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	2.20
Average Selection Frequency	178

SHA #36 (Map 27 and 28)	Northeast Cape Fear River – Watermelon Run
Description	Northeast Cape Fear River at Watermelon Run
Acres	1,427
Prominent Habitats	Forested wetland
Ecological Designations	AFSA
Conservation Lands	None
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marina
Average Total Alteration Score	2.30
Average Selection Frequency	129

SHA #37 (Map 28)	Northeast Cape Fear River – Duplin/Pender County Line
Description	Northeast Cape Fear River at the Duplin/Pender county line
Acres	839
Prominent Habitats	Forested wetland
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	None
Prominent Alterations	Major NPDES and marinas
Average Total Alteration Score	2.14
Average Selection Frequency	184

5.6 Black River

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

SHA #39 (Map 30)	Black River
Description	Black River including mouth of Moores Creek
Acres	5,938
Prominent Habitats	Forested wetland
Ecological Designations	AFSA
Conservation Lands	Lower Black River Swamp, Black River Cypress Swamp, Upper Black River Bottomlands, Cape Fear River Wetlands Game Land, and Black River Preserve
Water Quality Ratings	Mostly supporting and some no data
Water Quality Classifications	None
Fish Data	WRC IBI sampling
Prominent Alterations	Major NPDES, marinas, and shellfish closure
Average Total Alteration Score	2.33
Average Selection Frequency	158

6 MAPS OF FINAL INDIVIDUAL STRATEGIC HABITAT AREAS

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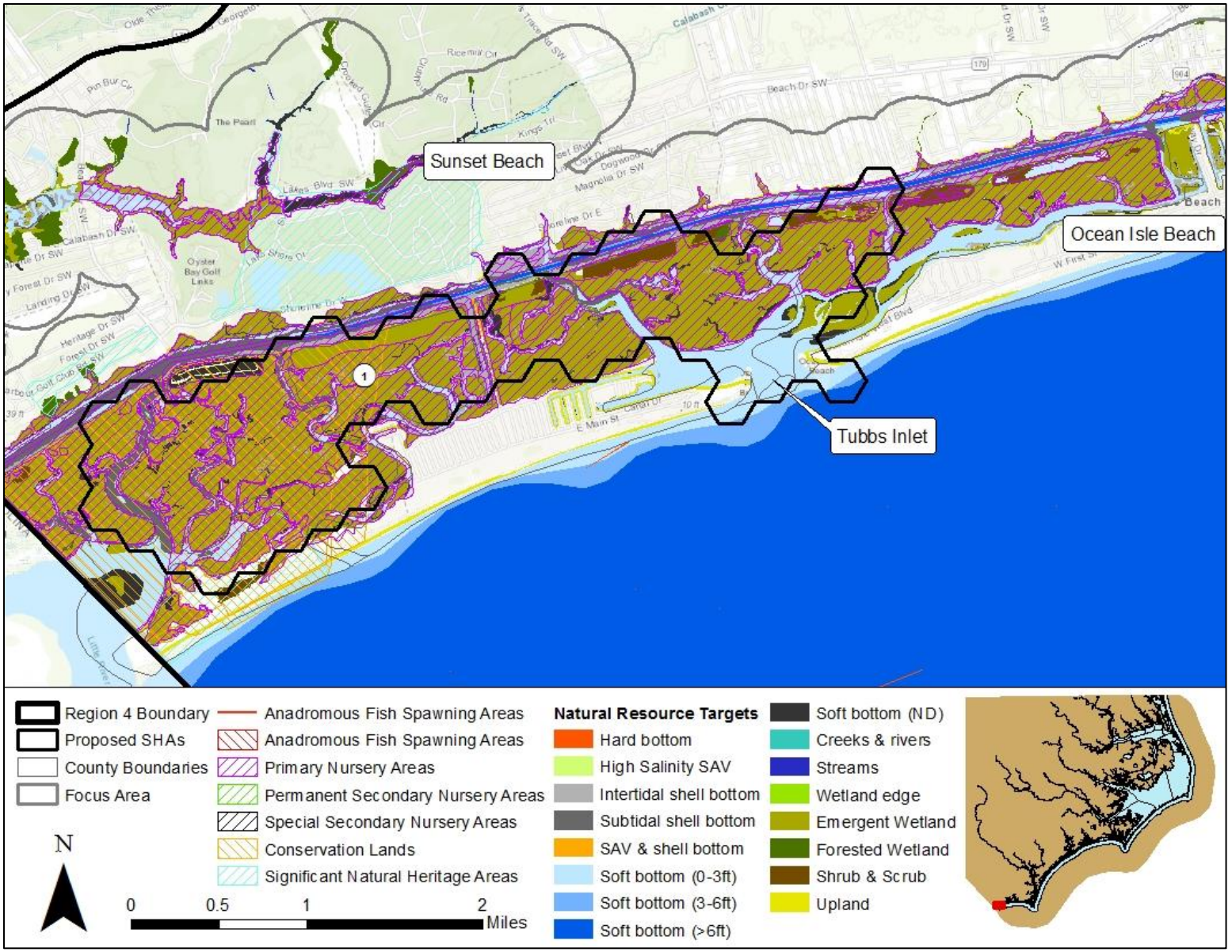
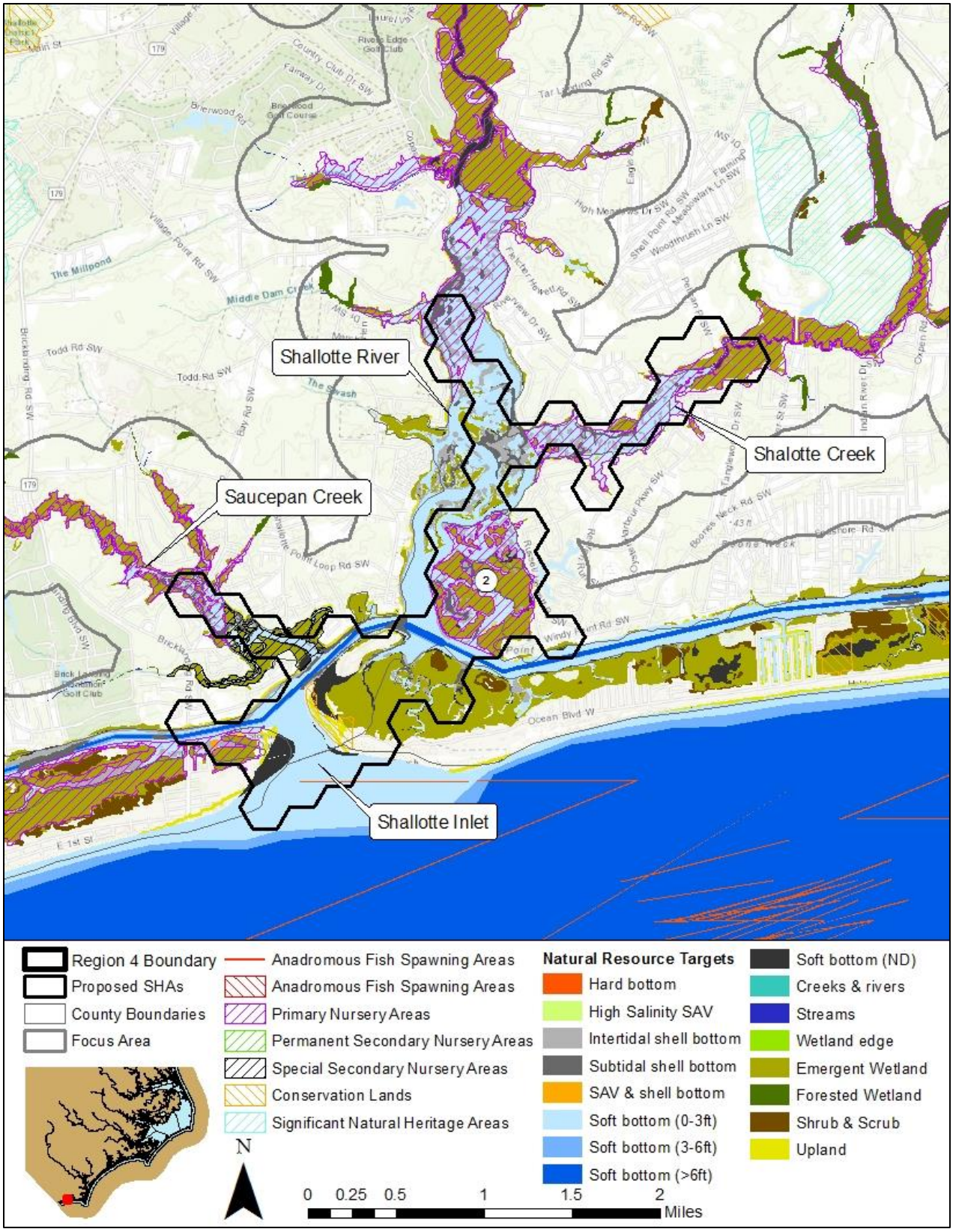
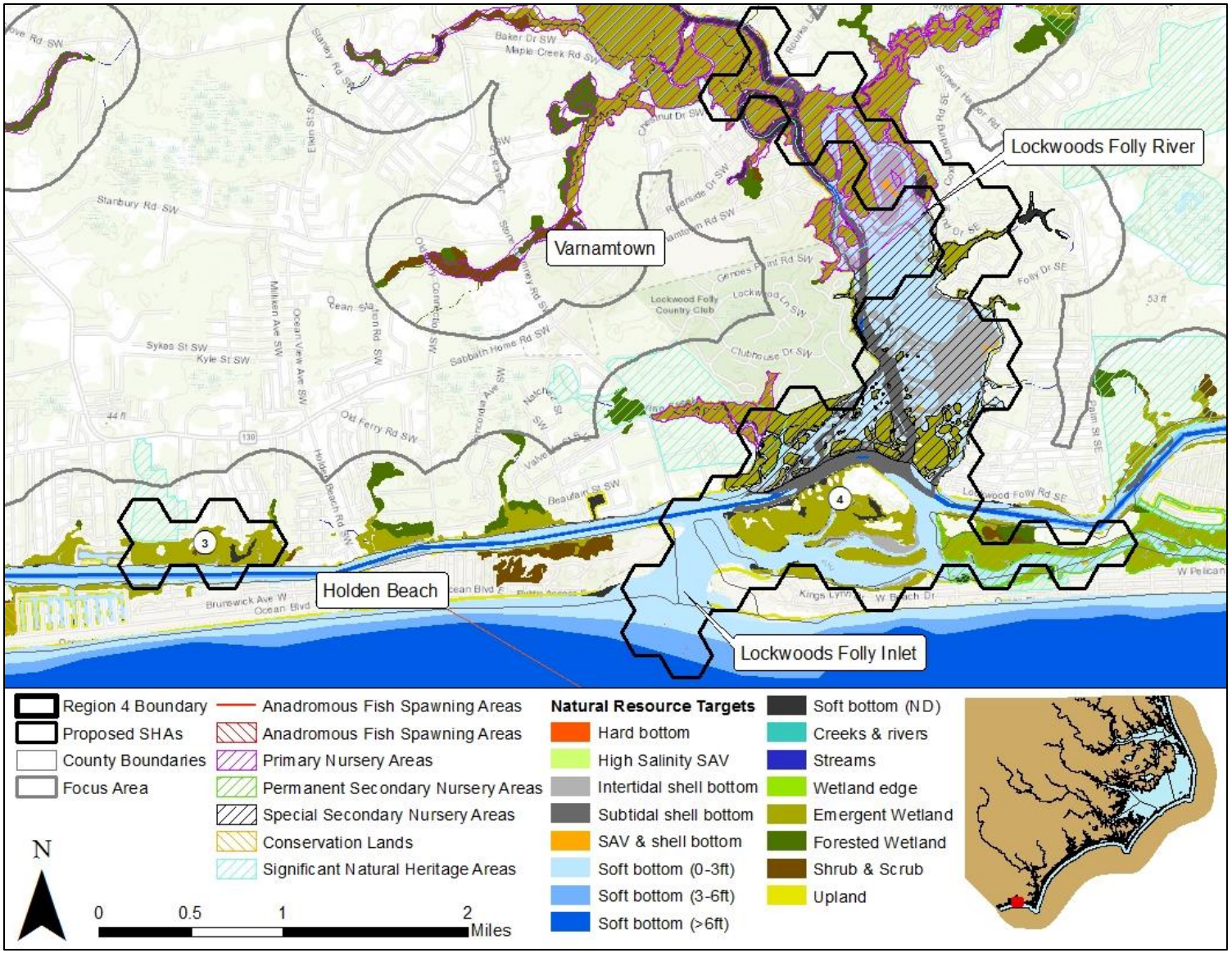


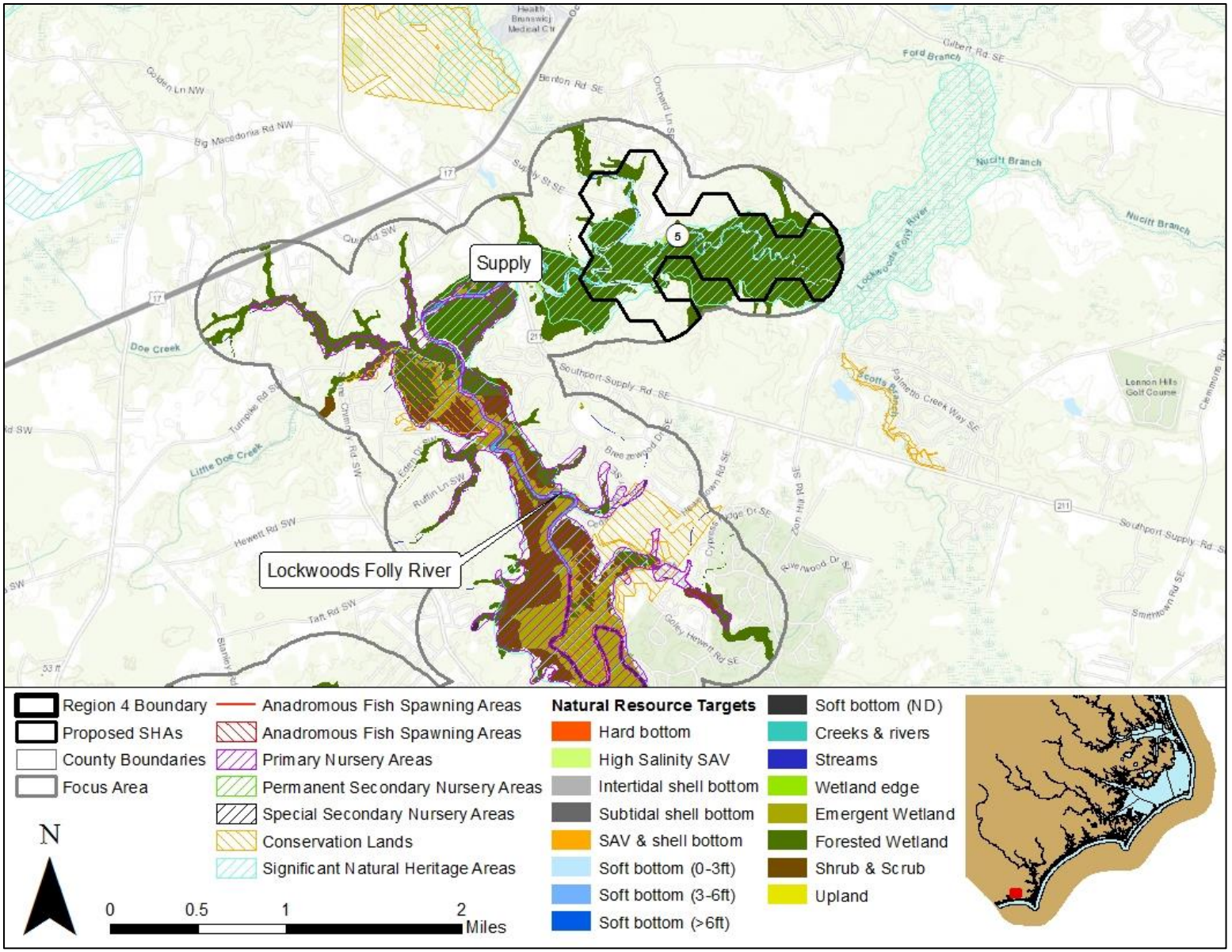
Map 10. Strategic Habitat Area (SHA) nomination #1, Sunset Beach – Bird Island to Tubbs Inlet.



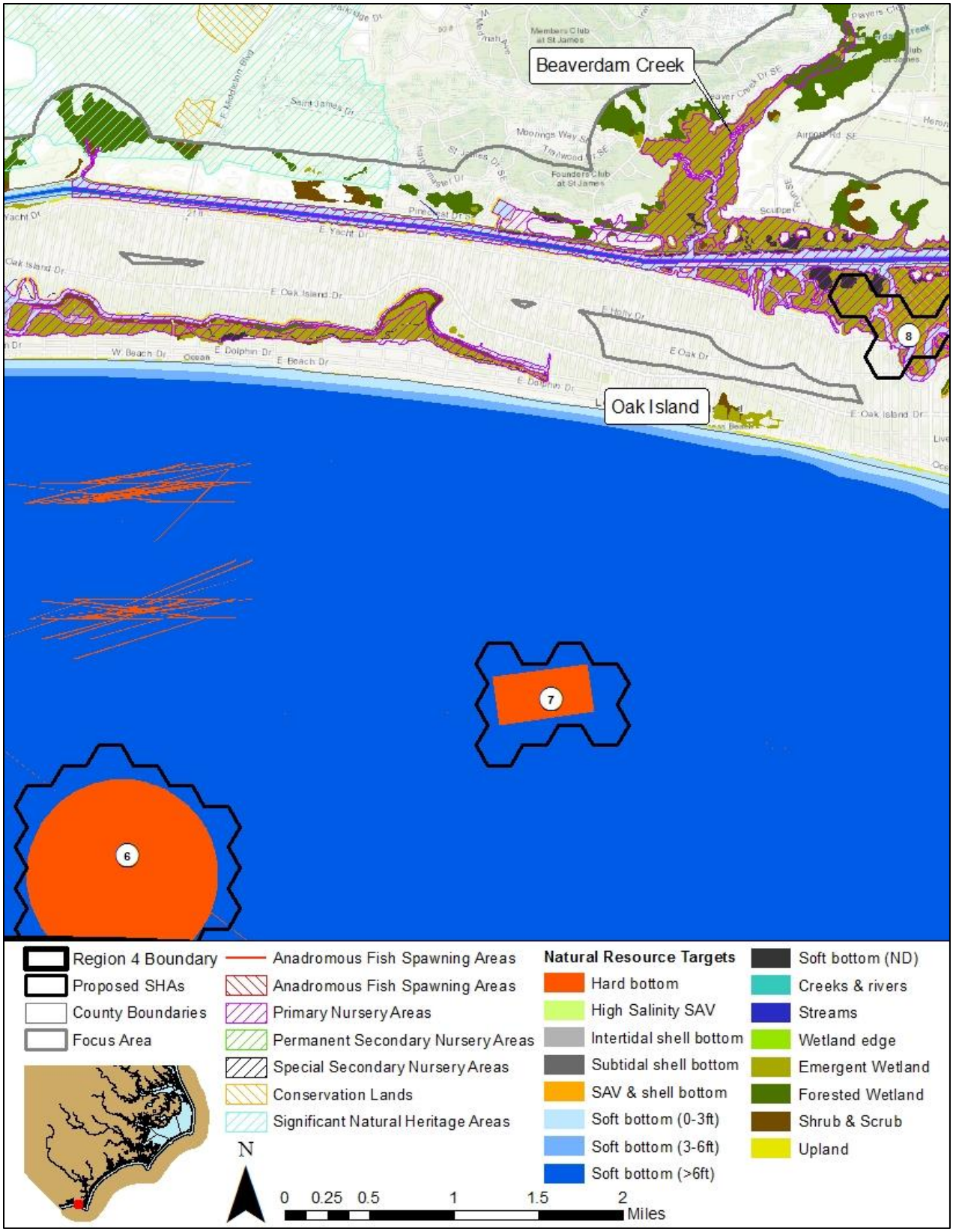
Map 11. Strategic Habitat Area (SHA) nomination #2 – Shallotte Inlet, mouth of Shallotte River, and Shallotte Creek.



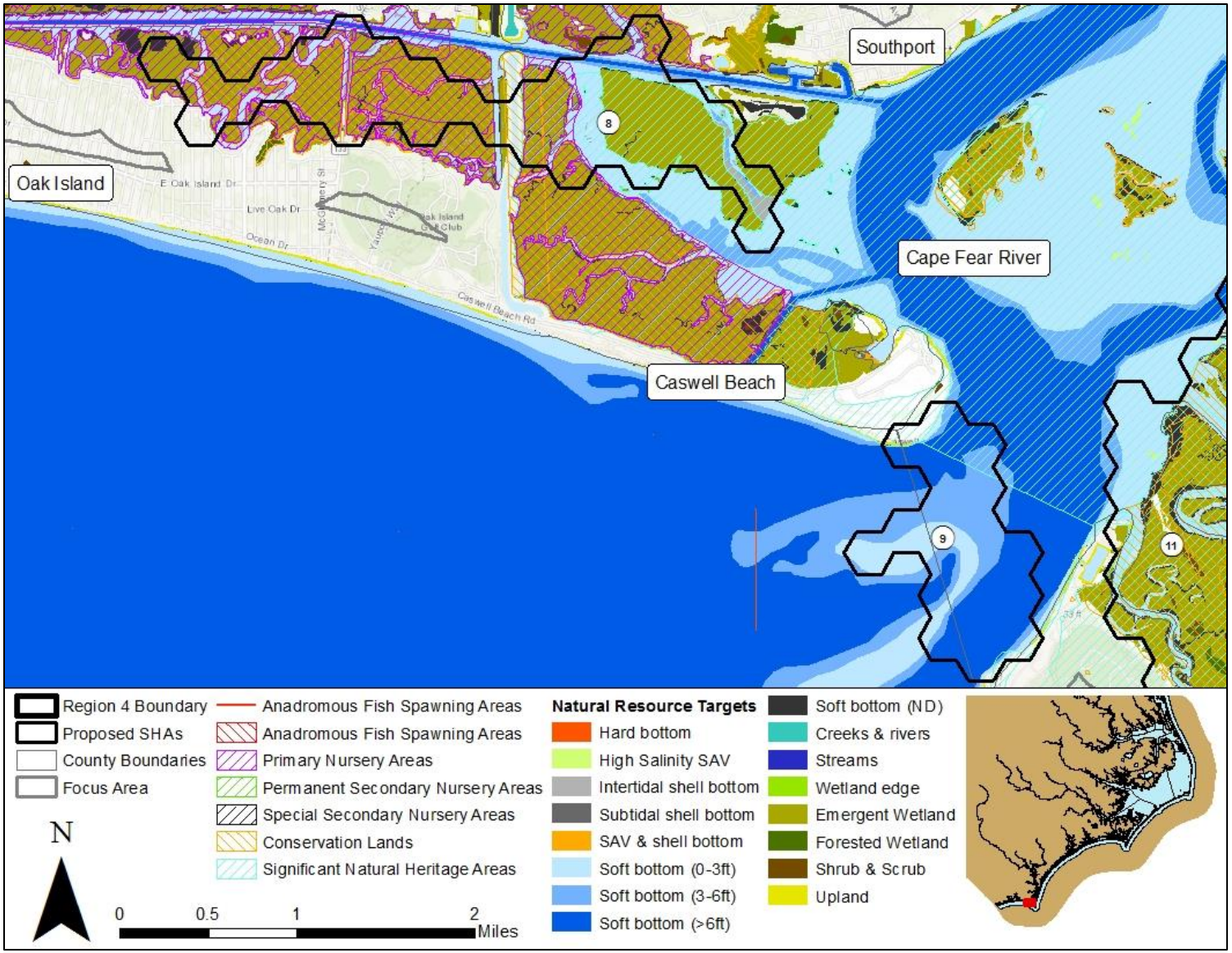
Map 12. Strategic Habitat Area (SHA) nominations #3 – Holden Beach and #4 – Lockwoods Folly Inlet, mouth of Lockwoods Folly River to Rourks Landing and Montgomery Slough.



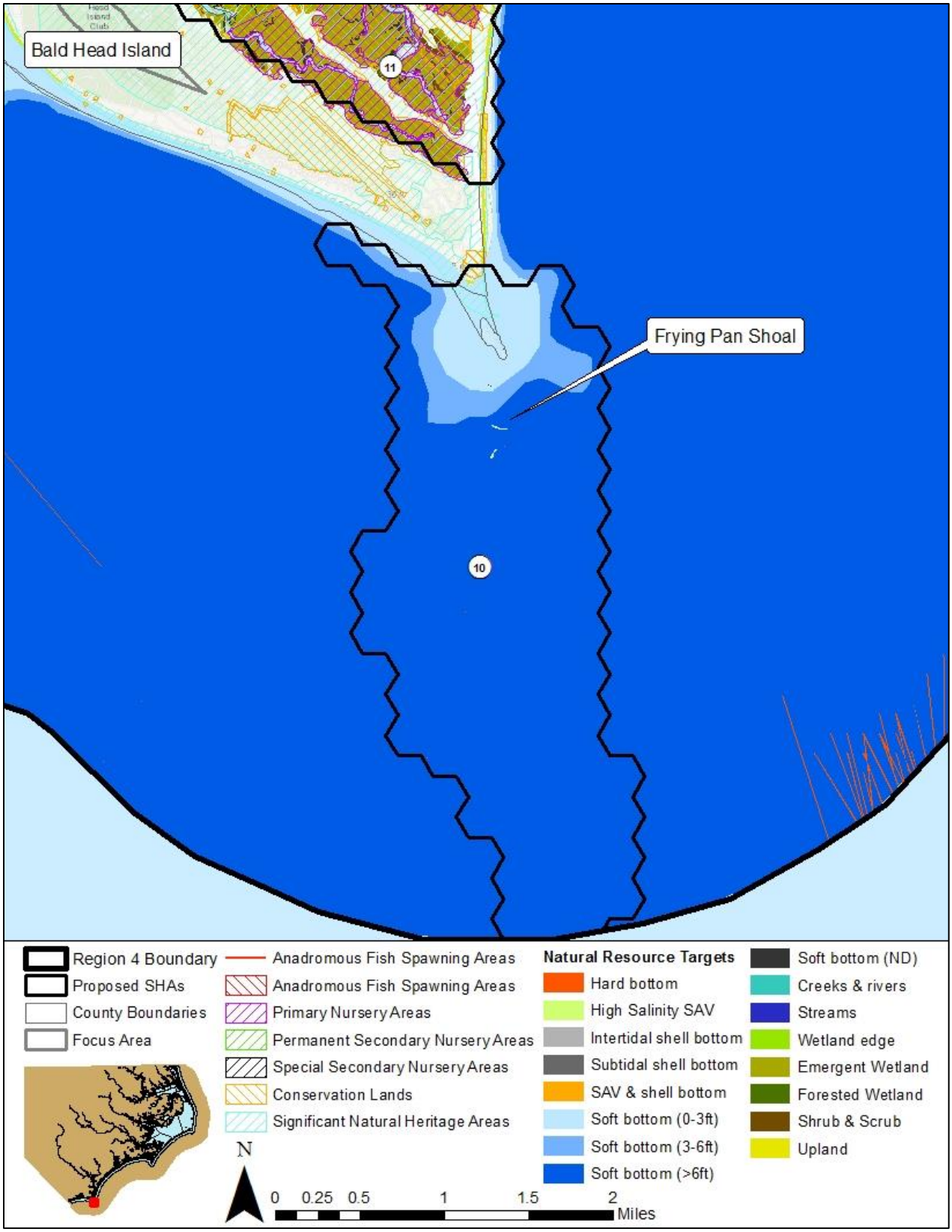
Map 13. Strategic Habitat Area (SHA) nomination #5 – Lockwoods Folly River northeast of Supply.



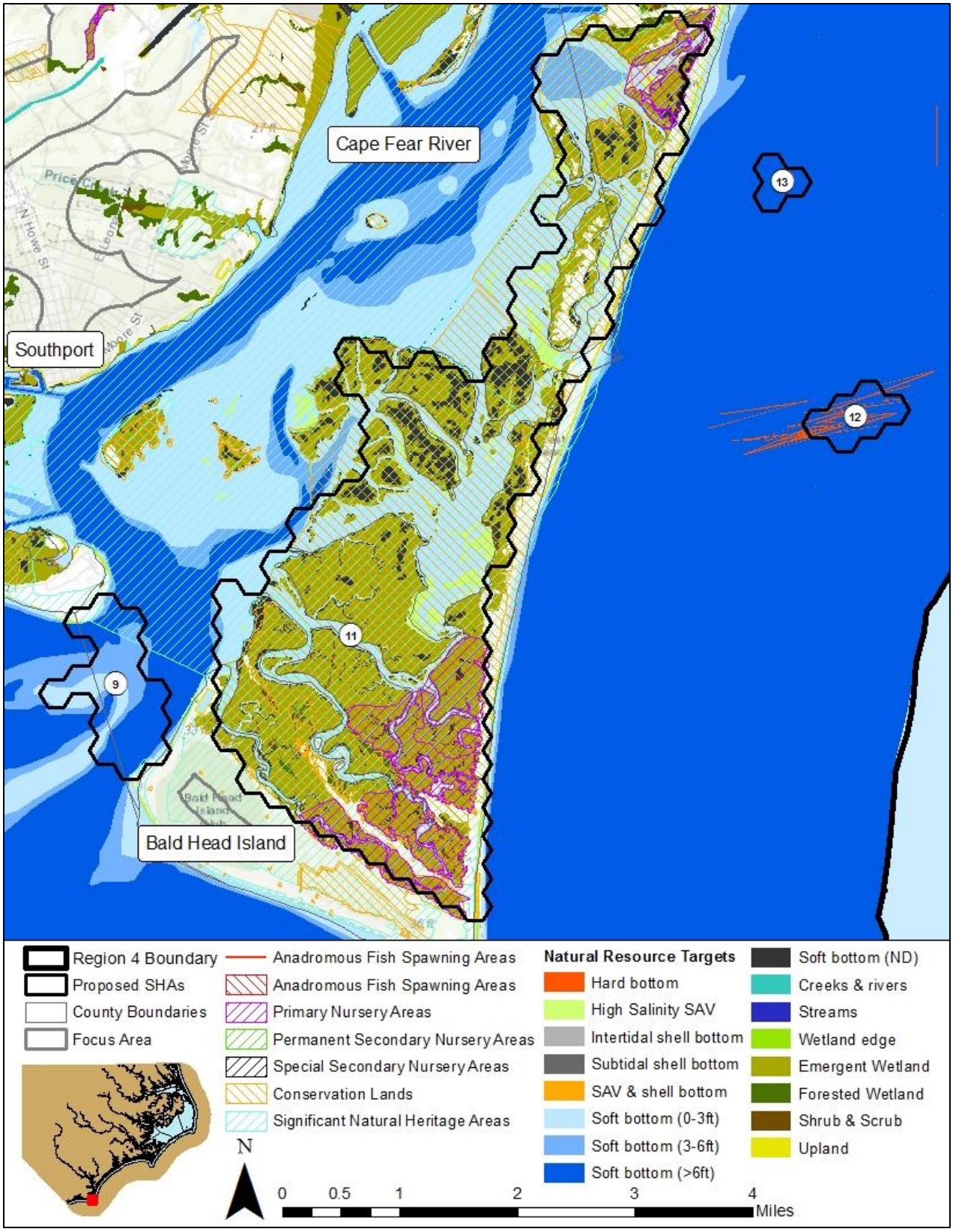
Map 14. Strategic Habitat Area (SHA) nominations #6 – Artificial Reef 430, #7 – Yaupon Beach reef, Artificial Reef 425, and part of #8 – Caswell Beach.



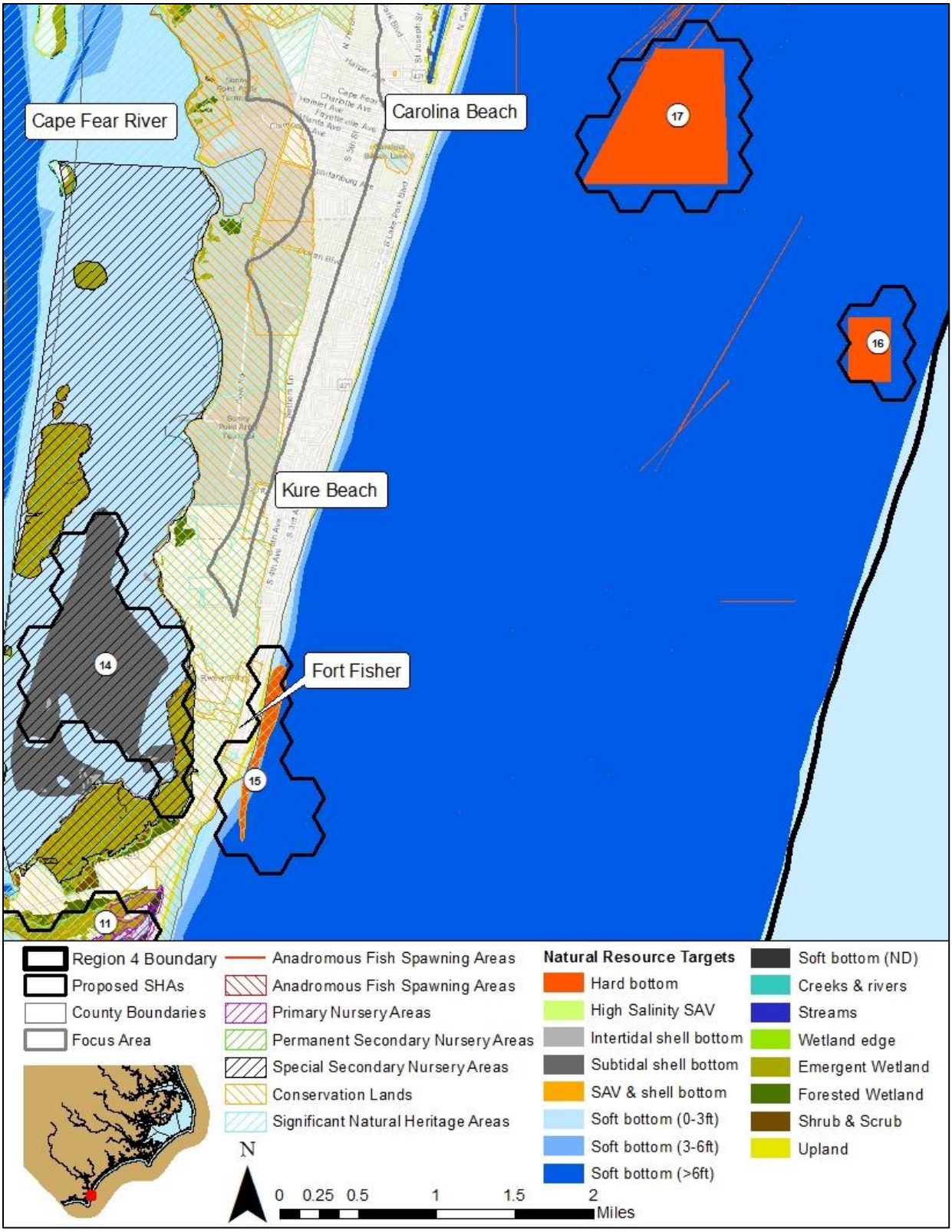
Map 15. Strategic Habitat Area (SHA) nominations #8 – Caswell Beach and #9 – Cape Fear River Inlet and part of #11 – Bald Head Island.



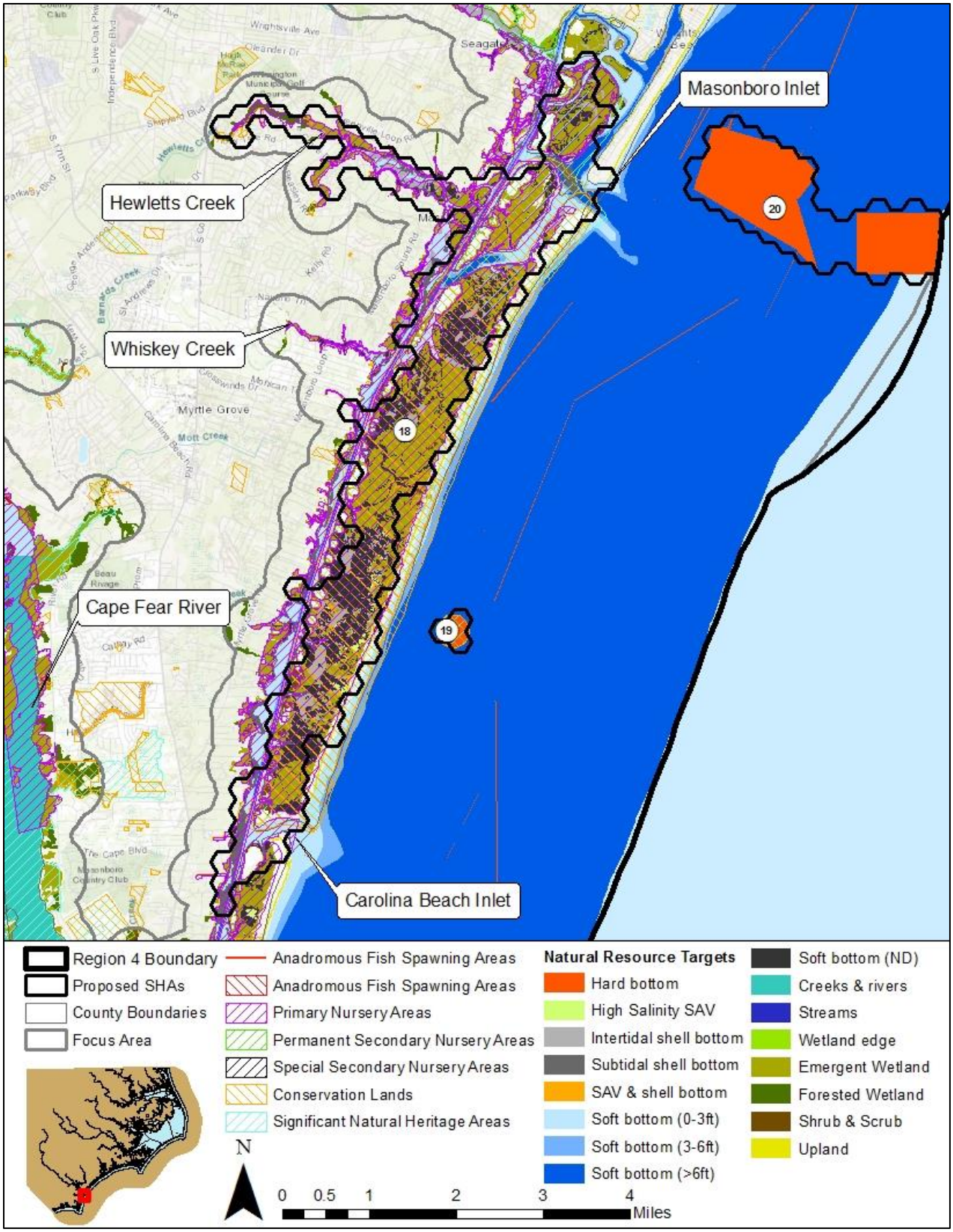
Map 16. Strategic Habitat Area (SHA) nominations #10 – Frying Pan Shoal and parts of #11 – Bald Head Island.



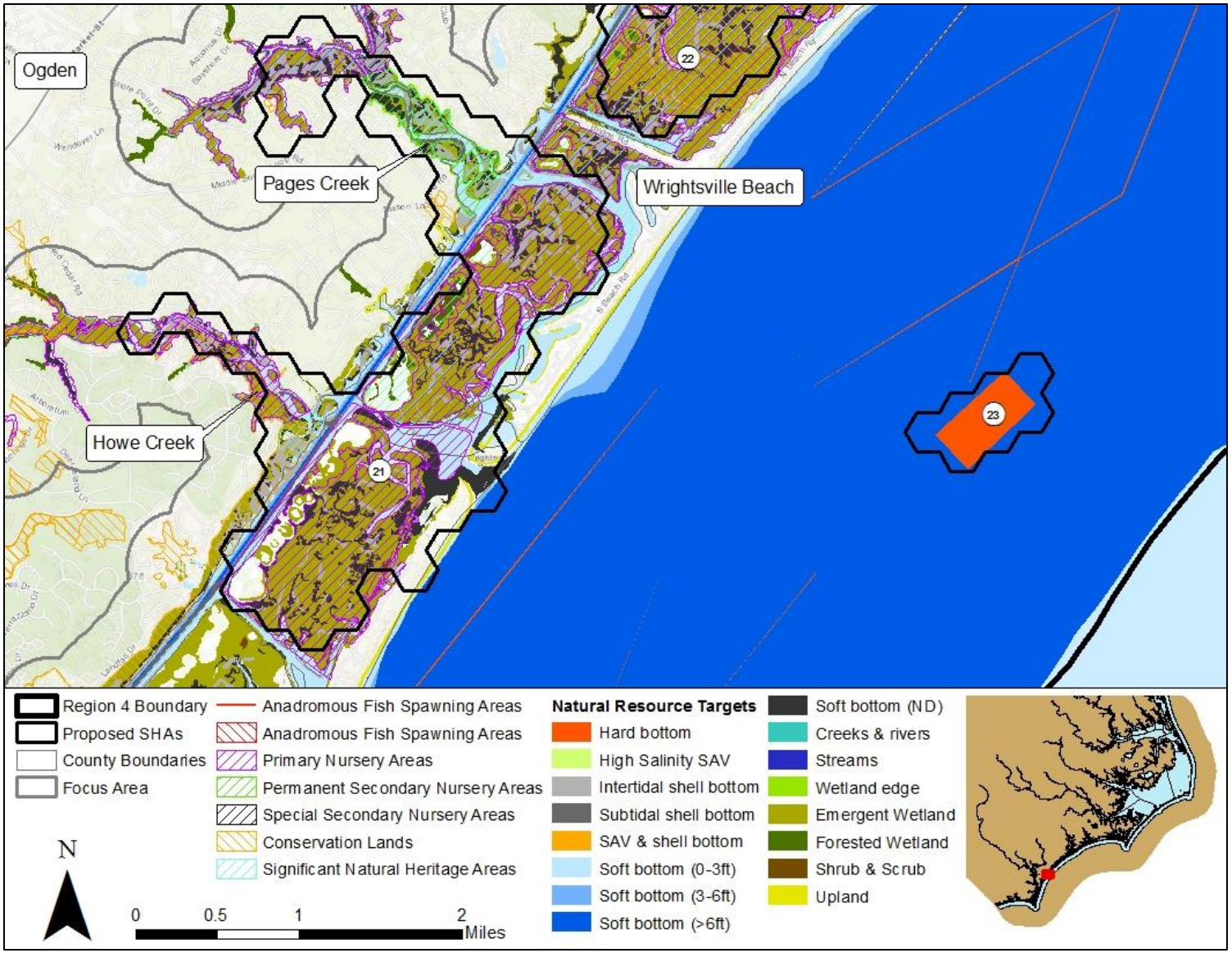
Map 17. Strategic Habitat Area (SHA) nominations #9 – Cape Fear River Inlet, #11 – Bald Head Island, #12 – hard bottom off Fort Fisher, and #13 – Sheepshead Rock.



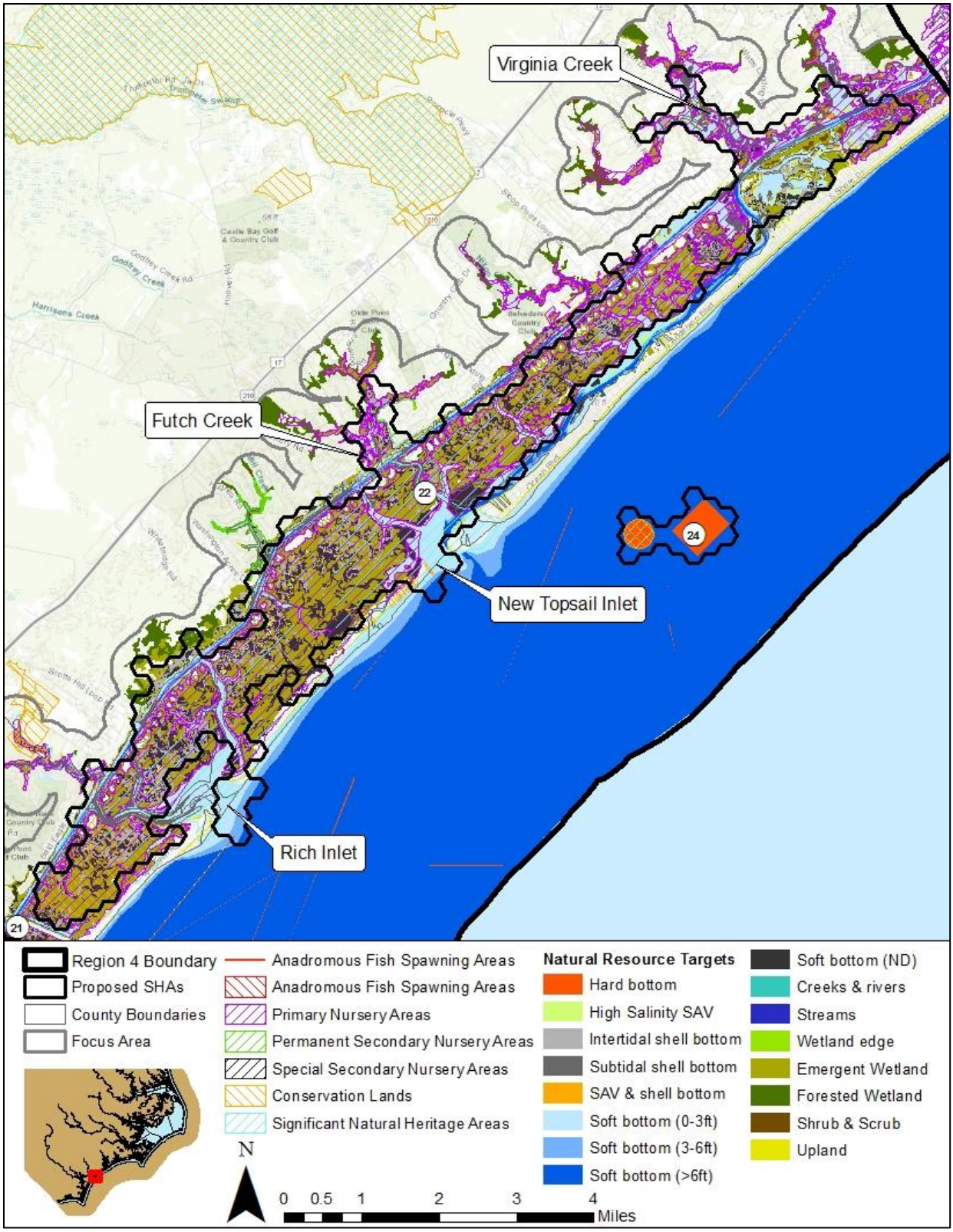
Map 18. Strategic Habitat Area (SHA) nominations #14 – Cape Fear River at Sunny Point, #15 – Fort Fisher Cocquina Outcrop, #16 – Artificial Reef 378B, and #17 – Phillip Wolfe Reef, Artificial Reef 378.



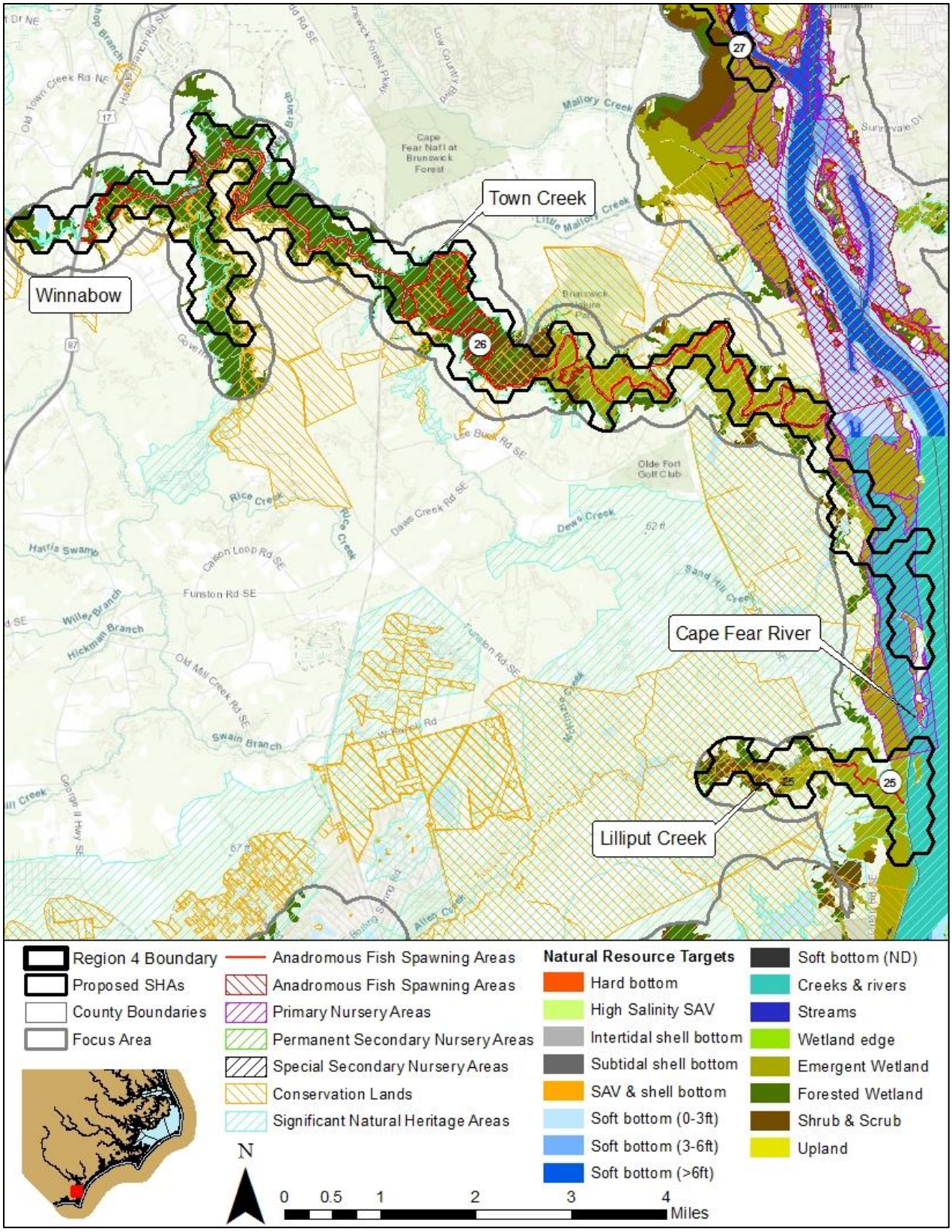
Map 19. Strategic Habitat Area (SHA) nominations #18 – Masonboro Island and Hewletts Creek, #19 – Masonboro Outcrop, #20 – Meares Harris, Artificial Reef 370.



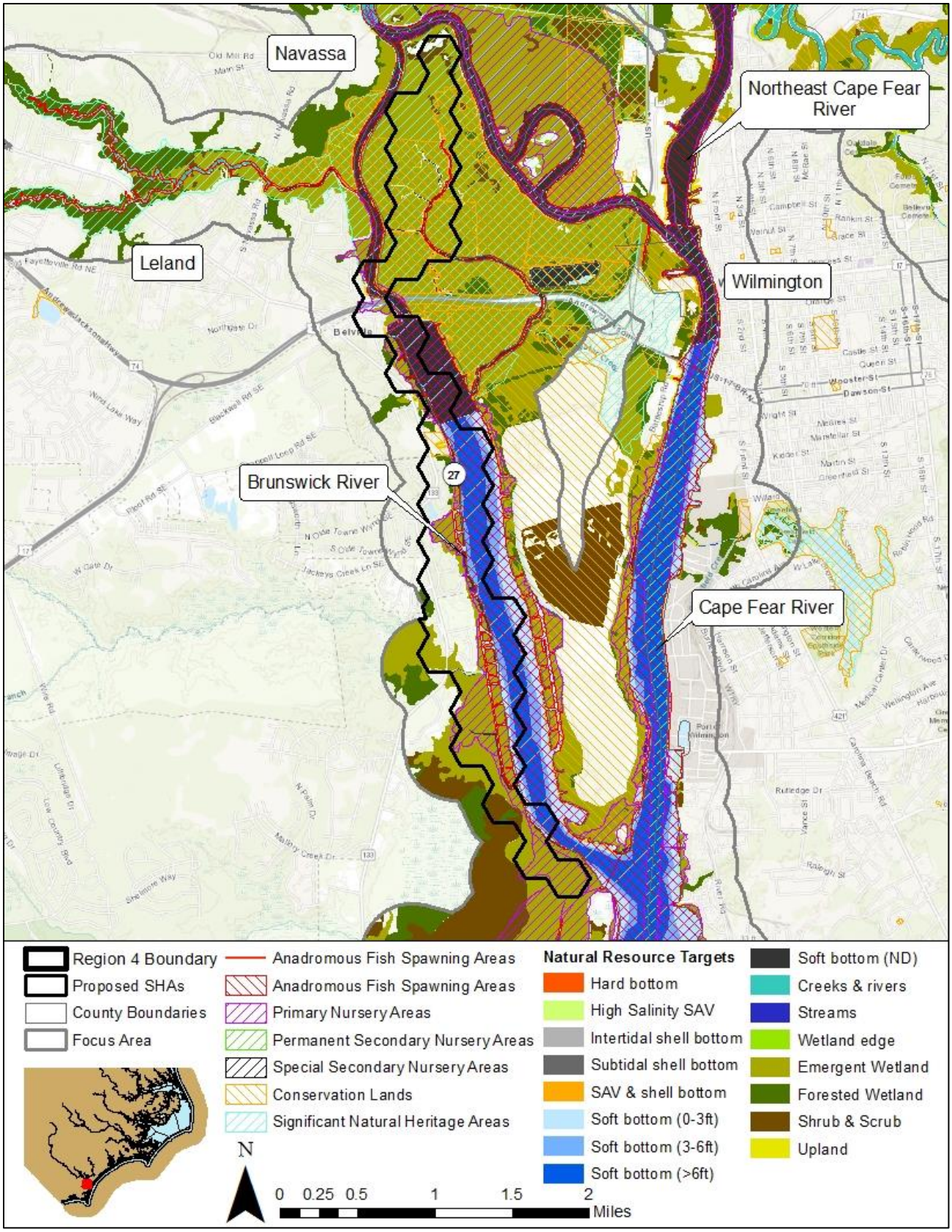
Map 20. Strategic Habitat Area (SHA) nominations #21 – Wrightsville Beach including Howe and Pages creeks, #23 – Billy Murrel Reef, Artificial Reef 364, and part of #22 – Topsail Beach.



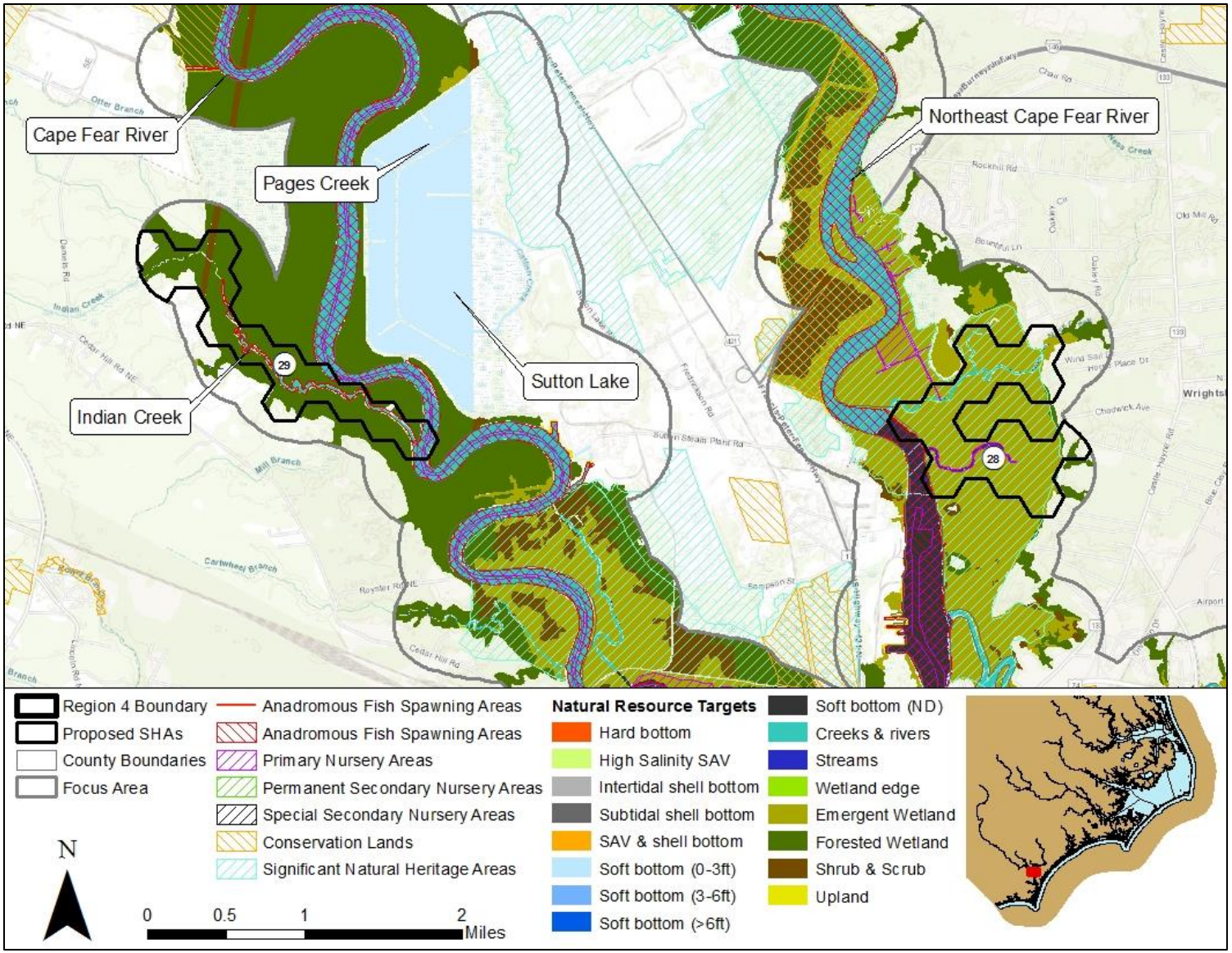
Map 21. Strategic Habitat Area (SHA) nominations #22 – Topsail Beach including Futch and Virginia creeks and Rich and New Topsail inlets and #24 – Topsail Reef, Artificial Reef 360.



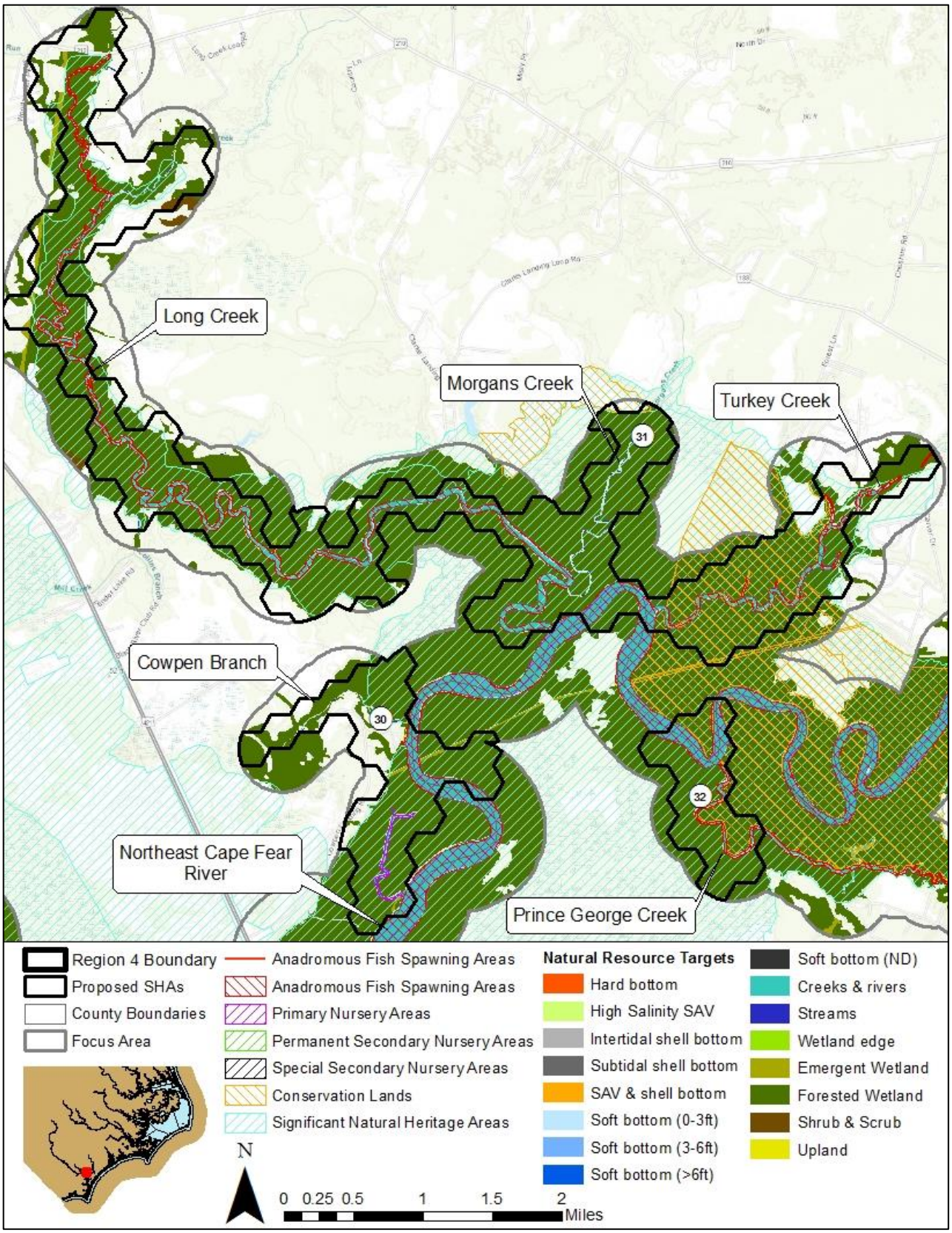
Map 22. Strategic Habitat Area (SHA) nominations #25 – Cape Fear River, Lilliput Creek and #26 – Cape Fear River, Town Creek.



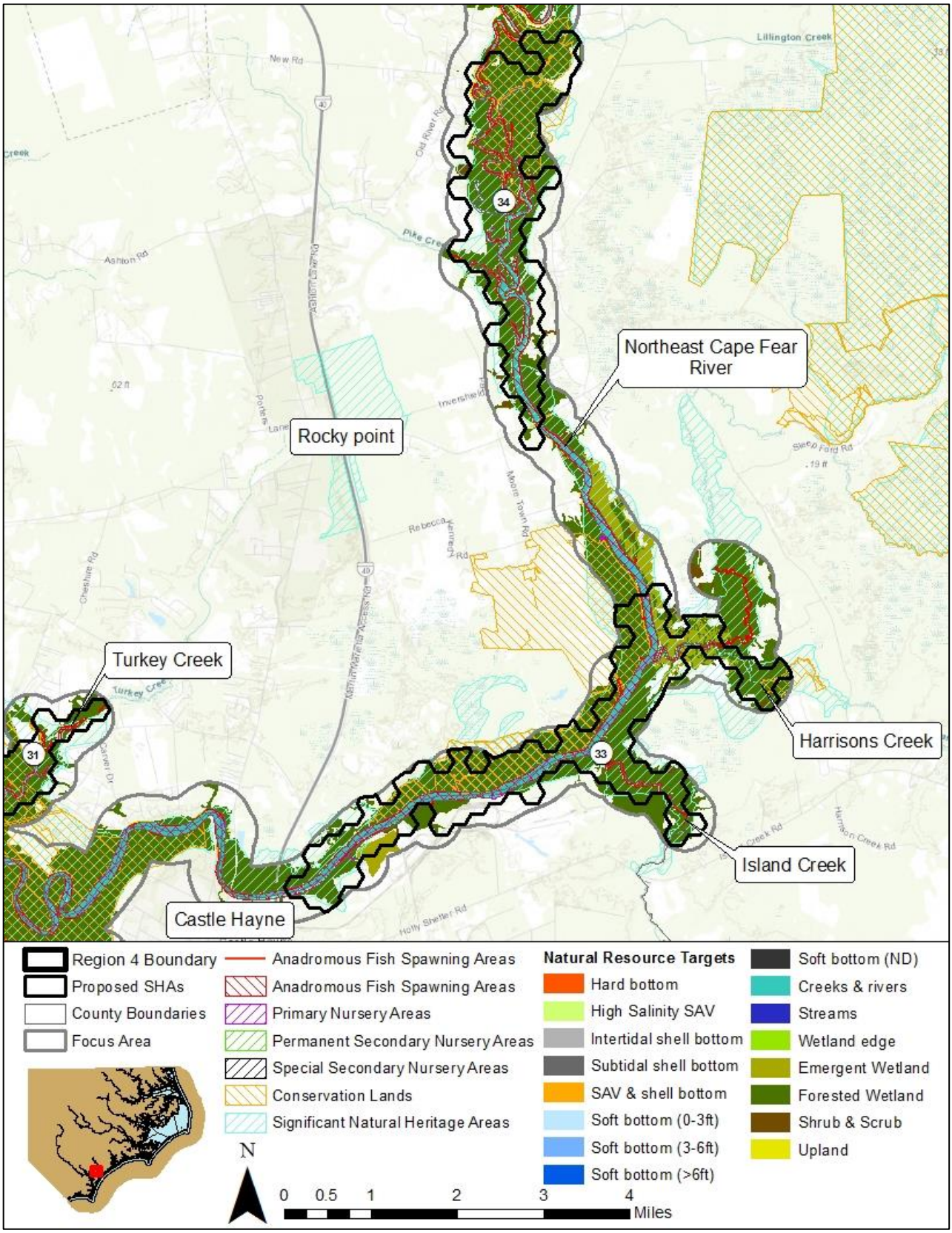
Map 23. Strategic Habitat Area (SHA) nomination #27 – Brunswick River.



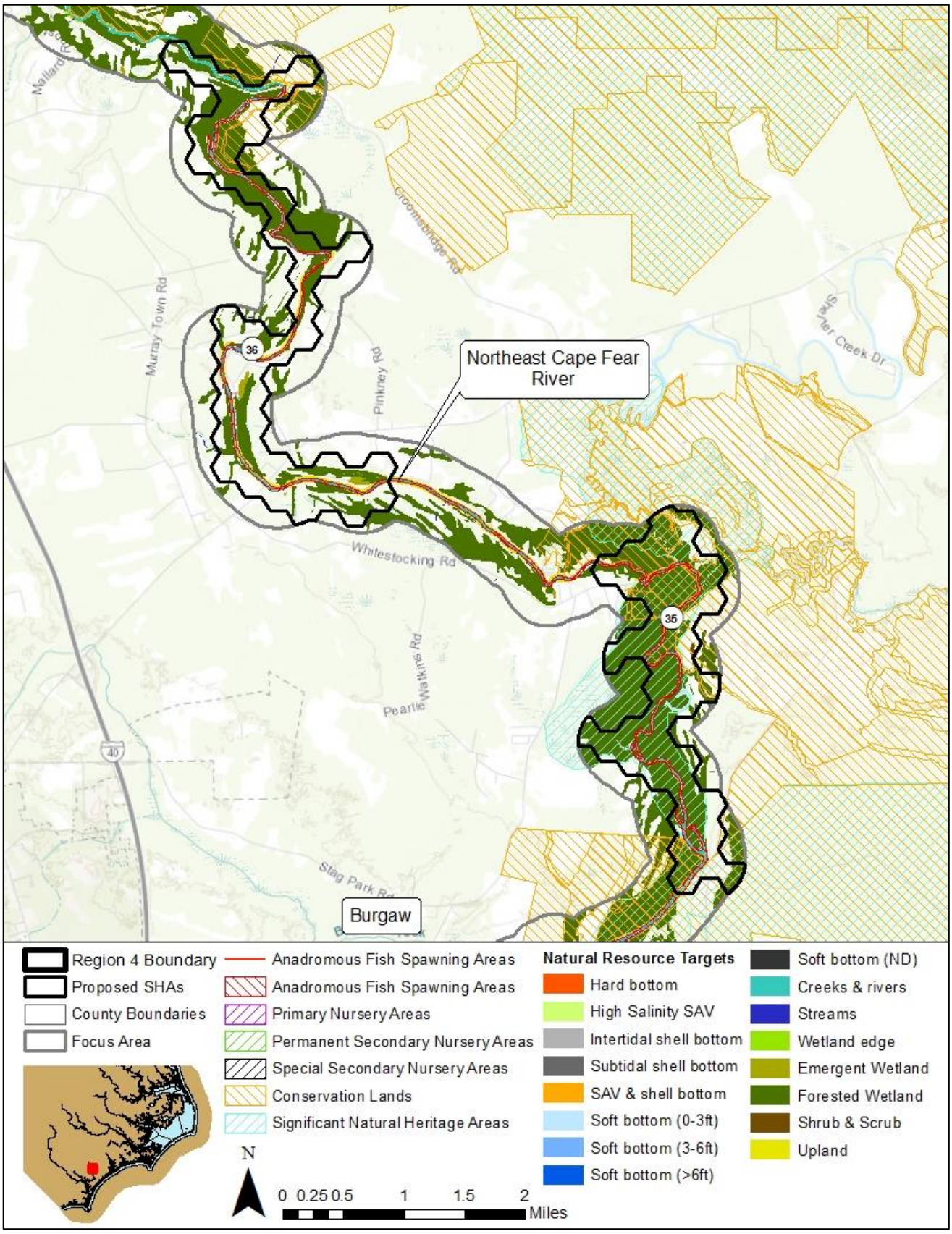
Map 24. Strategic Habitat Area (SHA) nominations #28 – Northeast Cape Fear River, Ness Creek and #29 Cape Fear River, Indian Creek.



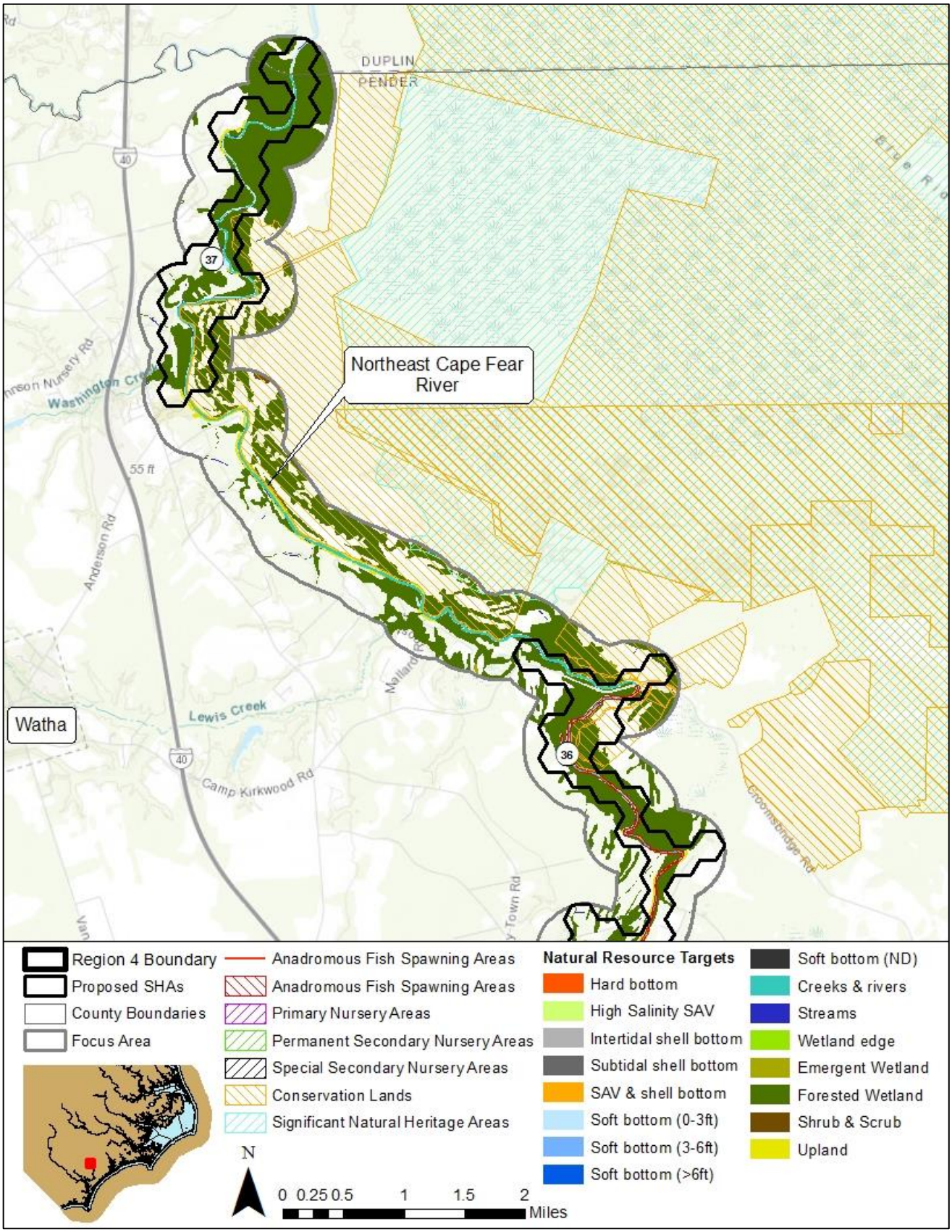
Map 25. Strategic Habitat Area (SHA) nominations #30 – Northeast Cape Fear River, Cowpen Branch, #31 Northeast Cape Fear River, Long, Morgans, and Turkey creeks, and #32 – Northeast Cape Fear River – Prince George Creek.



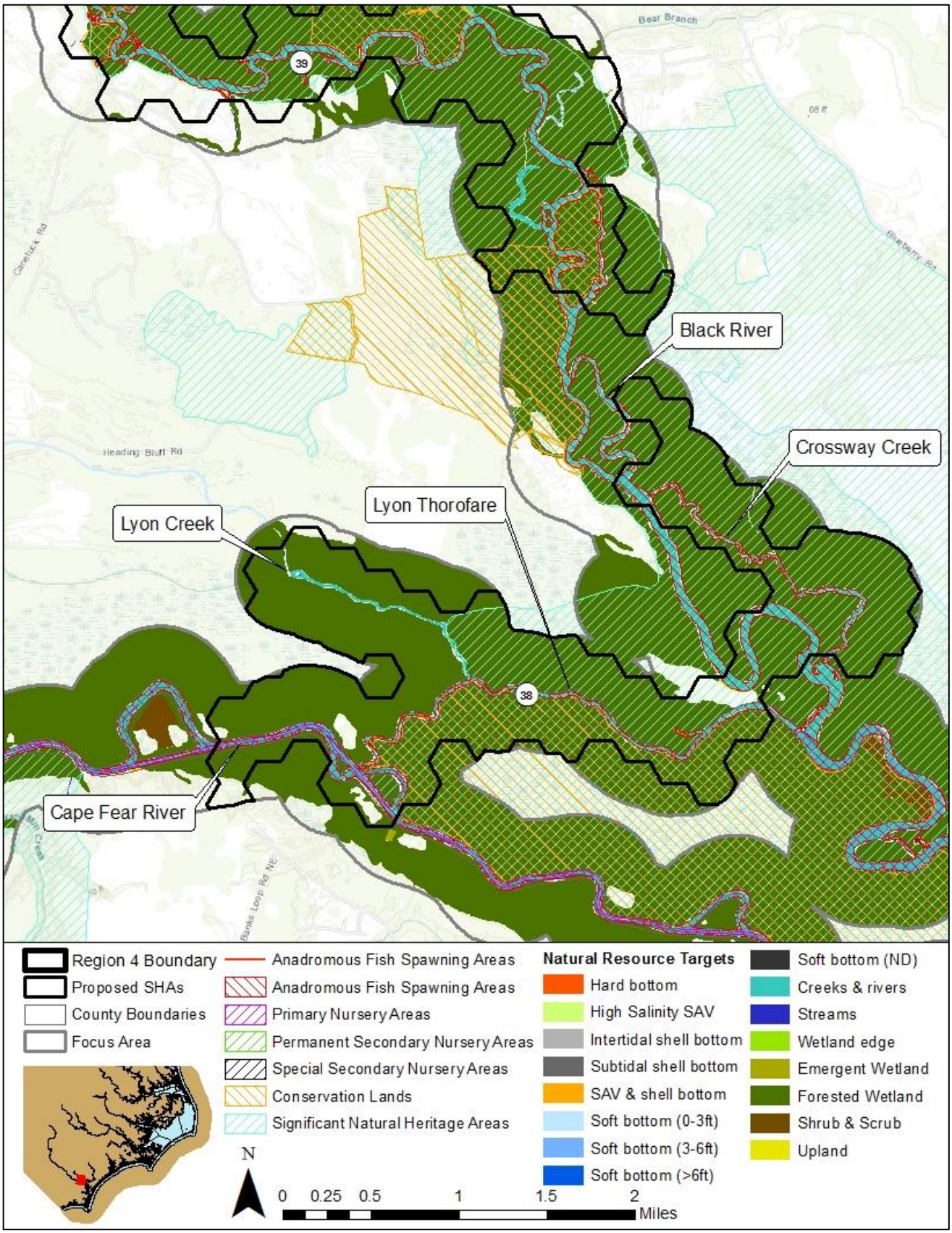
Map 26. Strategic Habitat Area (SHA) nominations #33 – Northeast Cape Fear River, near Castle Hayne including Island and Harrisons creeks and #34 – Northeast Cape Fear River, near Rocky Point.



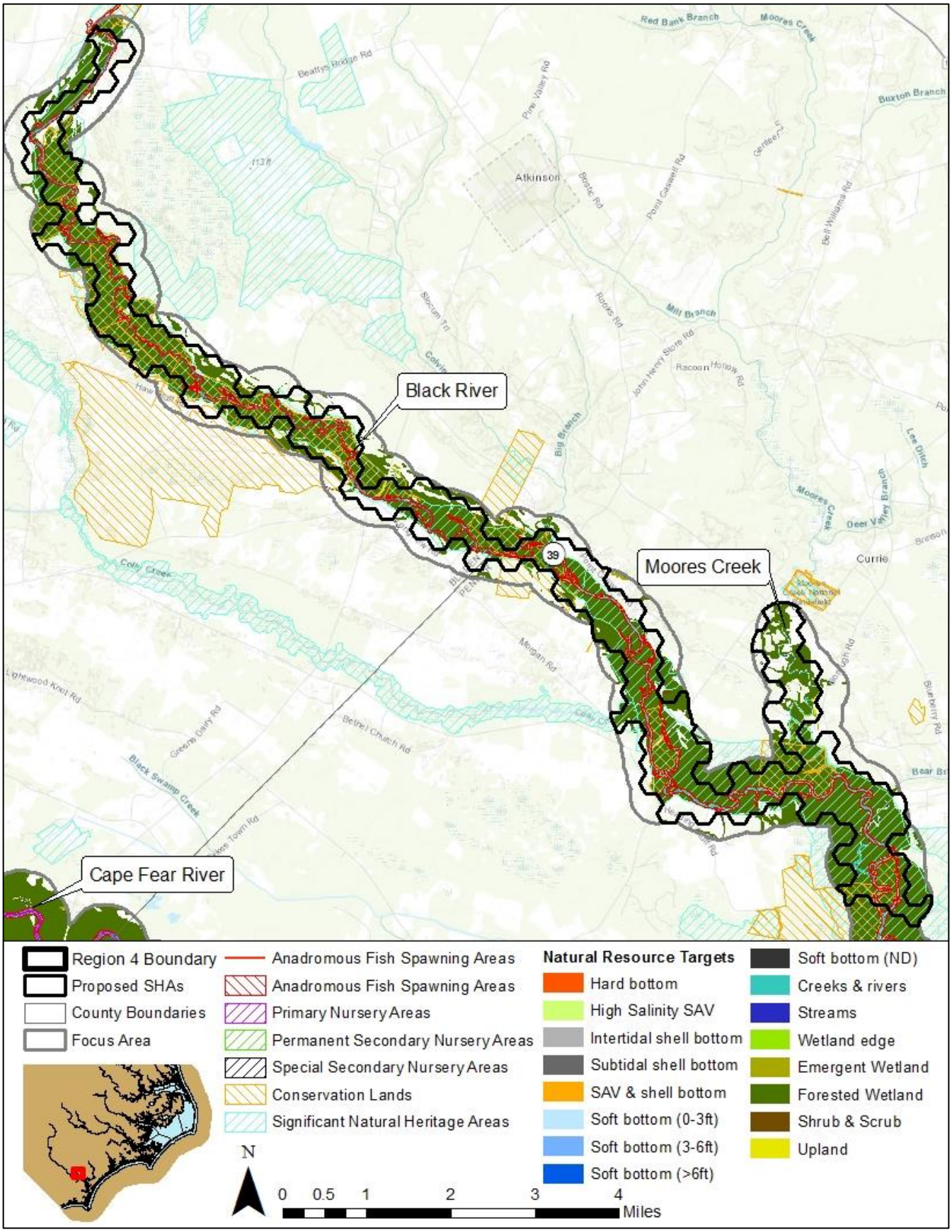
Map 27. Strategic Habitat Area (SHA) nominations #35 – Northeast Cape Fear River, Ashes Creeks and #36 – Northeast Cape Fear River, Watermelon Run.



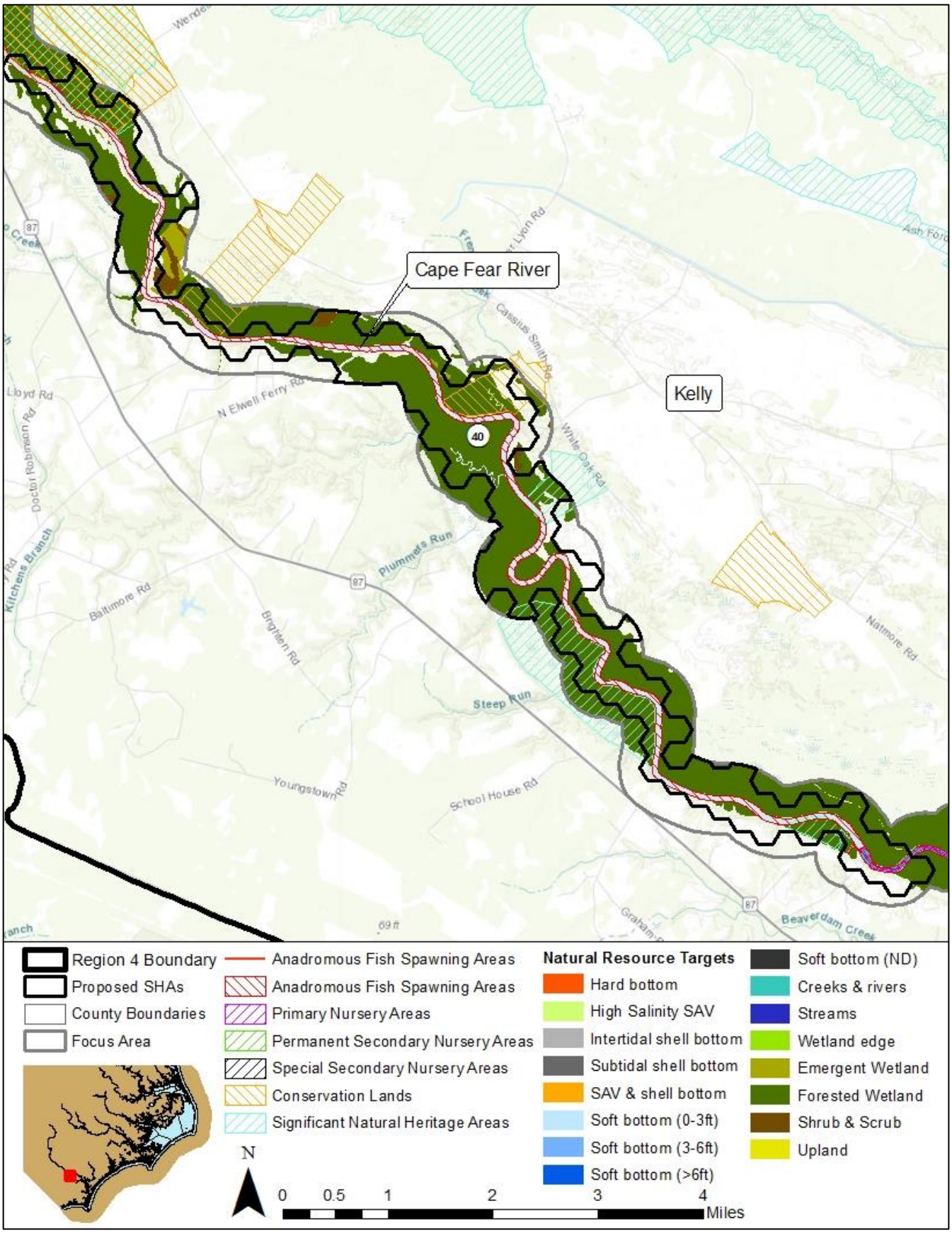
Map 28. Strategic Habitat Area (SHA) nominations #37 – Northeast Cape Fear River, Duplin/Pender County line and part of #36 – Northeast Cape Fear River, Watermelon Run.



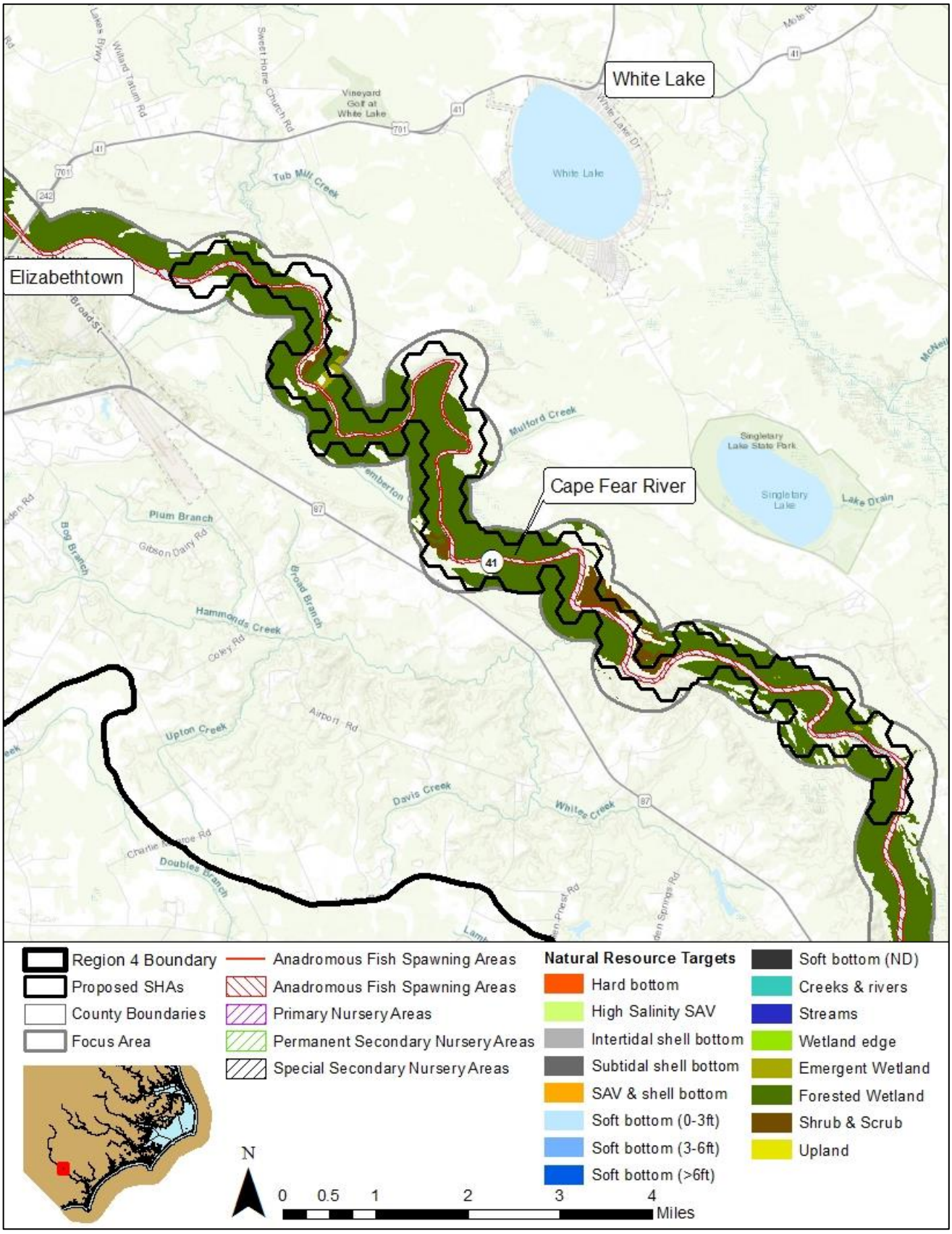
Map 29. Strategic Habitat Area (SHA) nominations #38 – Cape Fear River lowlands, Lyon and Crossway creeks and Lyon Thorofare and part of #39- Black River, Moores Creek.



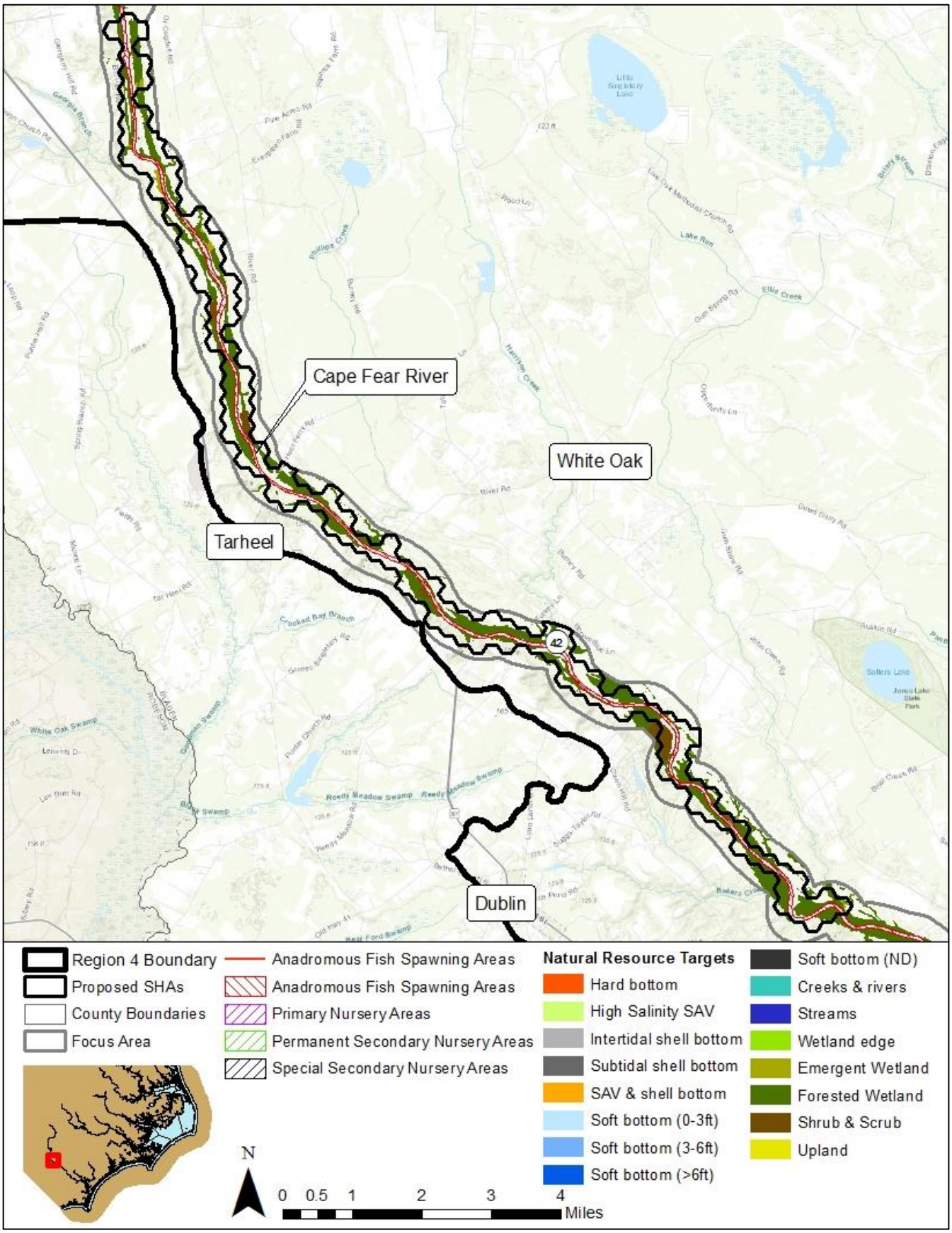
Map 30. Strategic Habitat Area (SHA) nomination #39 – Black River, Moores Creek.



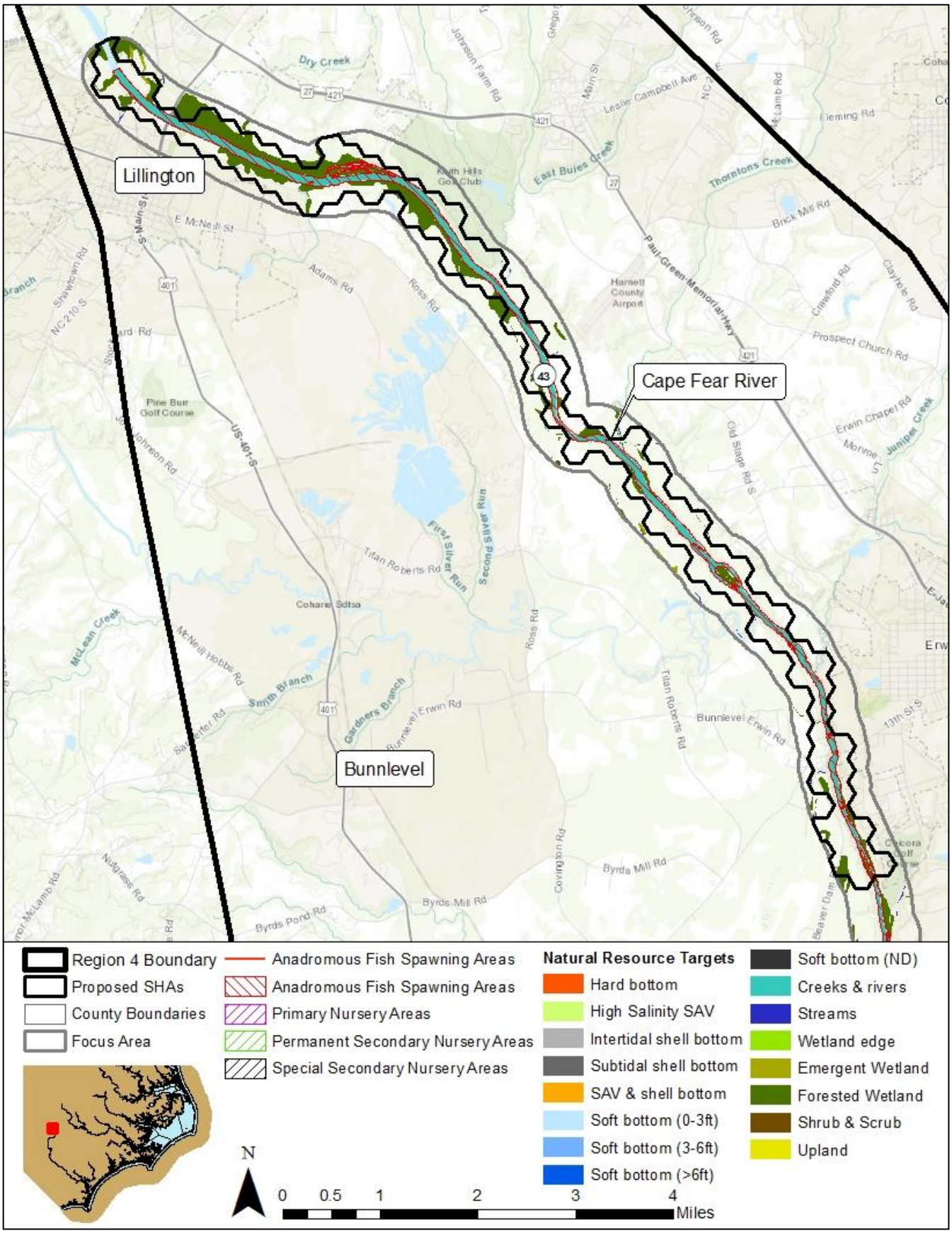
Map 31. Strategic Habitat Area (SHA) nomination #40 – Cape Fear River near Kelly.



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



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



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

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8 APPENDIX A: NATURAL RESOURCE TARGETS AND CALCULATING TOTAL ALTERATION

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

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

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

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

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

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

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

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

Extent (**E**) ratings were determined by calculating the percent of the habitat within the hexagon that is affected by the factor. For water-based factors (i.e. dredging), the threat may only overlap

with a portion of the habitat present. For land-based alteration factors calculated at the HU level, the **E** rating is simply 1 (complete overlap) for hexagons fully within a hydrologic unit.

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

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

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

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

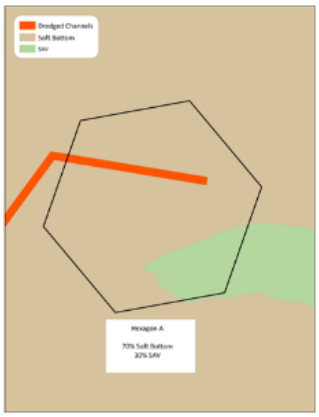

Table A.2. Calculation of hexagon alteration with only one alteration factor, but which occurs in some portion of two habitat types. S=severity, E=extent, P=portion

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

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

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

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

8.1 Processing Details

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

The process began by building a geodatabase of alteration data layers. Some manipulation was required to create the input layers for the alteration score. Tools were created using ArcGIS ModelBuilder with ArcGIS version 10.3. ModelBuilder allows the user to combine multiple tools and then execute them as a single process. The benefit to this approach was that it made the process transparent and easy to repeat.

The first step in creating the alteration score is to create the alterations habitat dataset. This is

stored in the field ALT_HABITA in the following steps. Below is a table showing the relationship between NRT types for Region 4 and the habitat types for alteration.

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

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

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

8.2 Data Processing

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

8.2.1 Aggregate point features by HU

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

8.2.2 Aggregate marinas by HU

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

8.2.3 Calculate marinas per shoreline

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

8.3 Extent Calculations

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

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

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

INPUTS:

1. Each land-based alteration factor of interest, aggregated by the hydrologic unit. All of these are polygon feature classes.

2. Alteration habitats feature class
3. Hexagon boundaries, with a unique ID
4. Hydrologic unit boundaries with a unique ID

OUTPUTS:

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

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

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

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

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

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

8.3.2 Water-based extent

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

INPUTS:

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

OUTPUTS:

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

Field Name	Description
ALT_HABITA	Habitat type for alteration.
canal_bb	Identifies the alteration present. One (1) for presence and zero (0) for absence.
brdge_cons	
impounded	
docks_br	
dredged	
drained	
mar_SGA	
clam_harv	
culverts	
trawl_perm	
Unique_ID	Hexagon assessment unit unique identifier.
alt_area	Area of alteration factor and habitat overlap, measured in square meters.

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

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

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

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

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

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

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

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

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

Field Name	Description
Unique_ID	Hexagon assessment unit unique identifier.
ALT_HABITA	Habitat type for alteration (only stream habitat type).
strm_leng	Length of stream habitat type per hexagon, measured in meters.

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

Field Name	Description
ALT_HABITA	Linear alteration shoreline habitat type (wetland edge or non-wetland

Unique_ID	Hexagon assessment unit unique identifier.
shoreline	Length of shoreline in hexagon assessment unit, in meters.

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

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

8.3.3 R Tools for use in calculating alterations

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

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

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

8.3.3.1 Water Based Severity Extent Calculation.r

Input files:

1. Table listing the overlapping area-based alterations and habitat combinations per hexagon with the following fields (**hab_alt_by_hex20170612.csv**):

a. **ALT_HABITA** – alteration habitat type, must be one of the following: "*creeks and rivers*", "*deep soft bottom*", "*shallow soft bottom*", "*SAV and shell bottom*", "*SAV*" , "*shell bottom*", "*soft bottom (ND)",* "*upland*", "*wetland*".
b. **Unique_ID** – unique hexagon assessment unit identifier.
c. **alt_area** – area of habitat intersection by the alteration factor in each hexagon.
d. Fields for any polygon based alterations considered. Currently, they include the following: "*canal_bb*", "*brdge_cons*", "i*mpounded*", "*docks_br*", "*dredged*", "*drained*", "*marinas*", "*major_npdes*", "*trawl"*
    i. Each row gives the presence/absence (1/0) of one specific factor for each hexagon.
    ii. Each hexagon has multiple rows, one for each habitat type x factor combination.

2. Table listing the overlapping line-based alterations and linear habitat combinations per hexagon with the following fields **(alt_lines_by_hex20170612.csv)**:
a. **ALT_HABITA** – alteration habitat type, must be one of the following: "S*tream" and "Wetland Edge".*
b. **Unique_ID** – unique hexagon assessment unit identifier.
c. **alt_length** – area of habitat intersection by the alteration factor in each hexagon.
d. Fields for any linear-based alterations considered. Currently, they include the following: "*canal_bb*", "*brdge_cons*", "i*mpounded*", "*docks_br*", "*dredged*", "*drained*", "*marinas*", "*major_npdes*", "*trawl*".
    i. Each row gives the presence/absence (1/0) of one specific factor for each hexagon.
    ii. Each hexagon has multiple rows, one for each habitat type x factor combination.

3. Table giving amount of each polygon habitat in each hexagon with the following fields (**hab_by_hex20170612.csv**):
a. **ALT_HABITA** – alteration habitat type.
b. **Unique_ID** – unique hexagon identifier.
c. **hab_area** – total area of particular habitat type within a hexagon.

4. Table giving amount of each linear habitat in each hexagon with the following fields (**lines_by_hex20170612.csv**):
a. **ALT_HABITA** – alteration habitat type.
b. **Unique_ID** – unique hexagon identifier.
c. **length_new** – total area of particular habitat type within a hexagon.

5. Alteration severity table (**alteration_factor_weighting_water20170515.csv**):
a. **ALT_HABITA** – habitat types (rows).
b. Alteration list – must match names exactly as they appear in the R alteration file (columns).

6. Seawalls by hexagon (**seawalls_by_hex20170612.csv**):
a. **ALT_HABITA** –linear habitat types for alteration (wetland and non-wetland shoreline).
b. **Unique_ID** – hexagon assessment unit unique identifier.
c. **wall_len** – length of seawall in hexagon.

7. Length of streams with an amount ditched attribute (**lines_by_ditched_by_hex20170612.csv**). Necessary attributes:
a. **Unique_ID –** hexagon assessment unit unique identifier.
b. **ALT_HABITA** – linear habitat type for alteration (streams only).

c. **ditch_le** – total length of ditched feature within each hexagon, measured in meters.
d. **prop_ditched** – proportion of total stream length that is ditched.
e. **length_new** – total amount of linear habitat type within each hexagon, measured in meters.

8. Length of streams with an attribute signifying the amount affected by culverts (**streams_by_culvert_by_hex20170612.csv**). Necessary attributes:
a. **Unique_ID** – hexagon assessment unit unique identifier.
b. **ALT_HABITA** – habitat type for alteration (streams only).
c. **culv_len** – length of culvert-affected features, measured in meters.

9. Length of shoreline affected by riprap (**riprap_by_hex20170612.csv**). Necessary attributes:
a. **Unique_ID** – hexagon assessment unit unique identifier.
b. **ALT_HABITA** – habitat type for alteration (non-wetland shoreline only).
c. **riprap_le** – length of riprap-affected shoreline, measured in meters.

Output files:

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

8.3.3.2 Land Based Severity Extent Calculations.r

Input files:

1. Table of factors for each hydrologic unit (**hu_alt_factors_table20170612.dbf**):
   a. **HU_12** – US Geological survey hydrologic unit code.
   b. **hu_area** – area of hydrologic unit in meters squared.
   c. *Scaled* values for the affected amount for each hydrologic unit:
      i. **min_npdes** – number of sites per hydrologic unit (includes aquaculture facilities) divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
      ii. **Cat_Swine_anops** – Number of cattle and swine operations per hydrologic unit divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
      iii. **Poultry_anops** – Number of poultry operations per hydrologic unit divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
      iv. **dev_use** – proportion of area of each hydrologic unit in the developed land use class.
      v. **ag_use** – proportion of area of each hydrologic unit in the agricultural land use class.
2. Table giving amount of each polygon habitat in each hexagon (**hab_by_hex20170612.csv**). The necessary attributes include:
   a. **ALT_HABITA** – polygon habitat type for alteration.
   b. **Unique_ID** – hexagon assessment unit unique identifier.
   c. **hab_area** – area of habitat in meters squared.

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

Output file:

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

8.3.3.3 Alteration Scores.r

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

Inputs:

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

Outputs:

1. **AltScore_by_Hex20170613.csv** - combined alteration scores for all hexagons. Attributes:
    a. **ID** – hexagon assessment unit unique identifier.

b. **R4_alt_score** – alteration score

2. **hab_scores20170612.csv –** alteration scores broken down by habitat type per hexagon. One line per hexagon gives the severity * extent * portion for each habitat type in each hexagon.
3. **ind_scores_20170612.csv** - alteration scores broken down by alteration factor by hexagon. One line per hexagon gives the severity * extent * portion for each alteration factor for each hexagon.

9 APPENDIX B: PREPARING THE MARXAN FILES

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

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

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

9.1 Species File (spec.dat)

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

Example species file:

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

9.2 Planning Units File (pu.dat)

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

Example planning unit file:

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

9.3 Boundary Tile (bound.dat)

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

Example boundary file:

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

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

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

Example planning unit vs species file.

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

9.5 The Input File (input.dat)

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

9.6 Marxan Resources:

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

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

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

Game, E.T. and H.S. Grantham, 2008. Marxan User Manual: For Marxan version 1.8.10. University of Queensland, St. Lucia, Queensland, Australia, and Pacific Marine Analysis and Research Association, Vancouver, British Columbia, Canada.

Watts, M.E., C.K. Klein, R. R. Stewart, I. R. Ball, and H. P. Possingham. 2008. Marxan with Zones (V1.0.1): Conservation Zoning using Spatially Explicit Annealing, a Manual.

10 APPENDIX C: DATA/INFORMATION DIRECTORY

Region 4 SHA Natural Resource Target and Alteration Factor GIS models and files:

See Appendix A: Natural Resource Targets and Calculating Total Alteration Section 8.1 Processing Details for further details.

S:\HABITAT\CHPP\SHA\Region 4\GIS\

Models\

1. SHA R4.tbx
2. Final Alteration Tools.tbx

Inputs\AlterationFactors\Finals

1. R4_Bridges.shp
2. R4_Bulkheads_RipRap_Final.shp
3. R4_CAFOsbyHUC.shp
4. R4_CAFOsbyHUC_Poultry.shp
5. R4_Canals_Boat_Basins.shp
6. R4_CCAP_2010_AgHUC_Final.shp
7. R4_CCAP_2010_DevHUC_Final.shp
8. R4_Culverts.shp
9. R4_Dams.shp
10. R4_Ditched_Final.shp
11. R4_DocksandPiers.shp
12. R4_DredgedChannels.shp
13. R4_Major_NPDES_HUC.shp
14. R4_Marinas_SGA_Closures.shp
15. R4_Mechanical_clam_harvesting_areas.shp
16. R4_Minor_NPDES_HUC.shp
17. R4_ProhibitedShellfishHarvest.shp
18. R4_Trawling_allowed

Inputs\Boundaries

1. Region4.shp
2. R4_USGS_HUCs
3. R4_trip_ticket_water_bodies.shp
4. R4_Hex20170615.shp
5. R4_A24k_jurisditional_waters.shp
6. R4_500m_FocusArea.shp
7. R4_Hexagons225SL_FocusArea.shp

Inputs\NRTs\Finals

1. ALT_HABITA_Poly20170508.shp
2. NRT_by_Hex20170619.shp
3. R4_ContiguousWetlands_W_FA.shp

4. R4_HardBottom_Final.shp
5. R4_NRTs_20170619.shp
6. R4_SAV_Final.shp
7. R4_SAV_ShellBottom_Final.shp
8. R4_ShellBottom_Final.shp
9. R4_Streams_Final.shp
10. R4_WetlandEdge_Final.shp
11. R4_WetlandEdge_w_FA.shp
12. StreamsUplandRiparian.shp

Region 4 SHA R script input/output files:

See Appendix A: Natural Resource Targets and Calculating Total Alteration Section 8.3 Extent Calculations for further details.

S:\HABITAT\CHPP\SHA\Region 4\GIS\Data

1. alt_lines_by_hex20170612.csv
2. alt_scores_20170612.csv
3. alteration_factor_weighting_land20170515.csv
4. alteration_factor_weighting_water20170515.csv
5. hab_alt_by_hex20170612.csv
6. hab_by_hex20170612.csv
7. hab_scores20170612.csv
8. hu_alt_factors_table20170508.csv
9. hu_by_hex20170612.csv
10. ind_scores_20170612.csv
11. LBSE_20170612.csv
12. lines_by_ditch_by_hex20170612.csv
13. lines_by_hex20170612.csv
14. NRT_by_hex20170613.csv
15. riprap_by_hex20170612.csv
16. seawalls_by_hex20170612.csv
17. shellfish_by_hex20170612.csv
18. shoreline_by_hex20170612.csv
19. streams_by_culvert_by_hex20170612.csv
20. WBSE_20170612.csv

Region 4 SHA R script files:

S:\HABITAT\CHPP\SHA\Region 4\GIS\R Scripts

1. alteration scores final_20170405.r
2. water based severity extent calculations_final.r
3. land based severity extent calculations_20170421.r
4. output_processing.r

Region 4 SHA Marxan files:

See Section 9 Appendix B: Preparing the Marxan files for further details.

S:\HABITAT\CHPP\SHA\Region 4\GIS\Marxan2.4.3

1. Marxan.exe
2. Inedit.exe
3. Input.dat

\input

1. Bound.dat
2. Pu.dat
3. Puvspr.dat
4. Spec.dat

11 APPENDIX D: PUBLIC COMMENT

In April 2018, input was sought regarding the SHA nominations at two MFC Advisory Committee meetings from committee members and the public. No public comment was received and both advisory committees recommended the MFC approve the proposed Region 4 SHAs without modification.

Advisory Committee	**Motion**	**Comments**
Southern	Recommend the commission approve the proposed Region 4 strategic habitat area nominations.	April 11, 2018 at the Wilmington Regional Office. No public comment was given. Motion approved unanimously (6-0).
Habitat and Water Quality	Recommend the commission approve the proposed Region 4 strategic habitat area nominations.	April 12, 2018 at the Washington Regional Office. No public comment was given. The quorum was not reached, but members present unanimously agreed on the recommendation.
DMF	Recommend the commission approve the proposed Region 4 strategic habitat area nominations.	