Strategic Habitat Area Nominations
for
Pamlico Sound System, North Carolina
(Region 2)

FINAL

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ACKNOWLEDGEMENTS

DEDICATION

This report is dedicated to Dr. Mark Brinson, who passed away suddenly while a member of the Region 2 Advisory Committee. He was also on the original SHA Process Advisory Committee and a long-standing member of the MFC's Habitat and Water Quality AC. His ideas and thoughts on identification of Strategic Habitat Areas greatly influenced the SHA Identification process. A thoughtful and engaged wetland ecologist, Mark was also cheerful, kind, professional, and a pleasure to work with. We'll miss him.

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LIST OF ABBREVIATIONS

NAME	Abbreviation
CGIA	North Carolina Center for Geographic Information
CHPP	NC Coastal Habitat Protection Plan
COE	United States Army Corps of Engineers
DCM	North Carolina Division of Coastal Management
DEH-SS&RWQ	North Carolina Division of Environmental Health – Shellfish Sanitation and Recreational Water Quality section
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
FWJ	North Carolina Fishing Water Jurisdictions
GIS	Geographical Information System
HU	Hydrologic unit
MARXAN	Site selection program
MFC	North Carolina Marine Fisheries Commission
NHD	National Hydrologic Dataset
NOAA	National Oceanographic and Atmospheric Administration
NRT	Natural resource targets
NWI	National Wetlands Inventory
NCSU	North Carolina State University
PCS	Potash Corporation of Saskatchewan Inc.
SAV	Submerged aquatic vegetation
SHA	Strategic Habitat Area
USACE	United States Army Corp of Engineers
VDEQ	Virginia Department of Environmental Quality
WRC	North Carolina Wildlife Resources Commission
WTP	Water treatment plant
WWTP	Waste water treatment plant

EXECUTIVE SUMMARY

Strategic Habitat Areas (SHA) represent priority habitat areas for protection due to their exceptional condition or imminent threat to their ecological functions supporting estuarine and coastal fish and shellfish species. Identification and designation of SHAs is a CHPP implementation action. 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. Staff and the advisory committee specified representation levels for 31 unique habitat types, or natural resource targets. There were also 24 alteration factors that were represented geospatially (i.e., hydrologic alterations, water quality degradation, etc.). The site selection program MARXAN was used to select areas that met representation levels while limiting selection of highly altered sites. The scientific advisory committee then modified the computer results based on their unique knowledge and experience. The resulting SHA nominations for 67 discrete areas encompassed 11% of Region 2 and 26% of the focus area (open waters and riparian targets within 500 m of the shoreline). Approximately 11% of the selected SHAs are state or federally owned lands, managed for conservation, or are protected through PNA designations. The SHAs were corroborated with biological data, ecological designations, and specific knowledge of the area. The SHA nominations will be incorporated into conservation and restoration planning efforts.
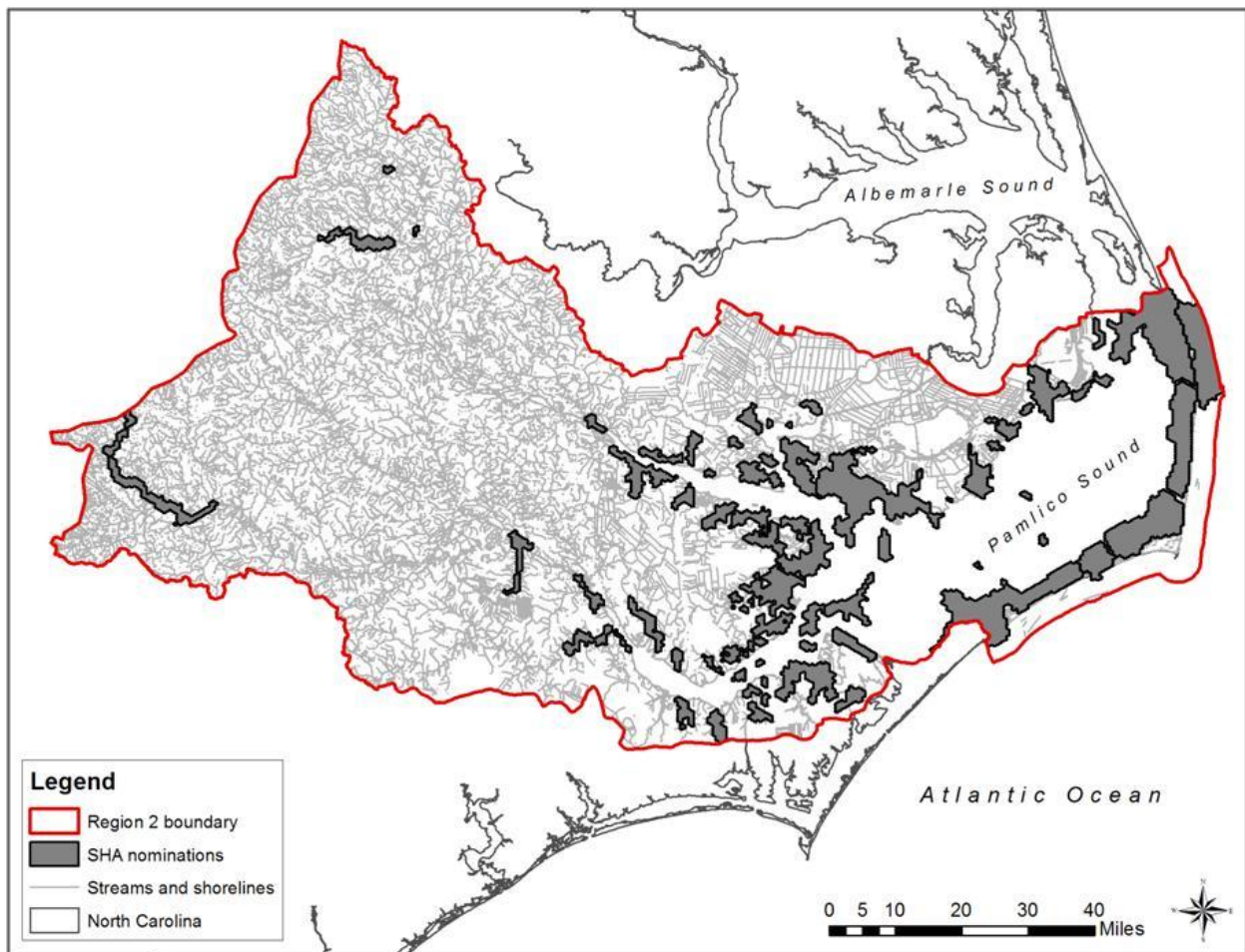
Map 1. Region 2 SHA nominations.

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). Criteria for identifying SHAs were developed by an advisory committee of the Marine Fisheries Commission established in summer 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 MFC-approved guiding document entitled, "Process for Identification of Strategic Habitat Areas" (DMF 2006)." This document is often referred to as the SHA report or guiding document.

SHA designations will be based on regional analyses that identify optimally placed habitat areas of various ecological condition (exceptional or at risk). SHAs 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 SHA will require various site-specific regulatory and/or non-regulatory management actions that best address the threats affecting that site. A network of designated SHAs providing habitat connections throughout North Carolina's coastal waters should 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 the system as a whole. Thus, the necessary protections for some areas may go above and beyond current measures designed to protect habitat. In addition to regulatory changes, the nomination of SHAs can 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). The current rules and policies of the resource management agencies fail to adequately address the individually small but cumulatively large conversions and alterations of fish habitat for development and associated human activities (Street et al. 2005, Deaton et al. 2010). 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). The 2010 CHPP update included a recommendation to develop the tools for addressing cumulative impacts (Deaton et al. 2010). On a regional scale, the concept of managing ecosystems to avoid cumulative impacts is partially addressed by assessing the condition of natural resource targets based on the presence, extent, and influence of multiple alteration factors. Maintaining a healthy ecosystem, through focus on Strategic Habitat Areas, is based on the interdependent relationship between alteration factors, natural resource targets, and the spatial landscape. Averting threshold levels of cumulative alteration to SHAs could be accomplished with both regulatory and non-regulatory tools.

This report documents the selection of SHA candidates in Region 2, encompassing Pamlico Sound and its tributaries in eastern North Carolina, and follows the nomination report format specified in the guiding document (DMF 2006).

GEOGRAPHIC SCOPE OF REGION 2

Region 2 includes the waters and adjacent wetlands draining into and out of Pamlico Sound through both Oregon and Ocracoke Inlets to the adjoining coastal ocean (Map 2). It includes the sounds and tributaries of Pamlico Sound and the Tar-Pamlico and Neuse rivers up to the fall line separating Coastal Plains and Piedmont physiographic regions. The boundaries of the study area were based on the CHPP subregions of Pamlico Sound, Tar-Pamlico River, Neuse River, adjacent coastal ocean, Oregon Inlet and Ocracoke Inlet (Deaton et al. 2010). Region 2 (the Pamlico Sound system) and Region 1 (the Albemarle Sound

system) are interconnected by Oregon Inlet and Croatan and Roanoke Sounds. Because Oregon Inlet influences both systems, it was included in both Region 1 and 2. Together, the Albemarle-Pamlico Sound system comprises the second largest estuary in the United States.
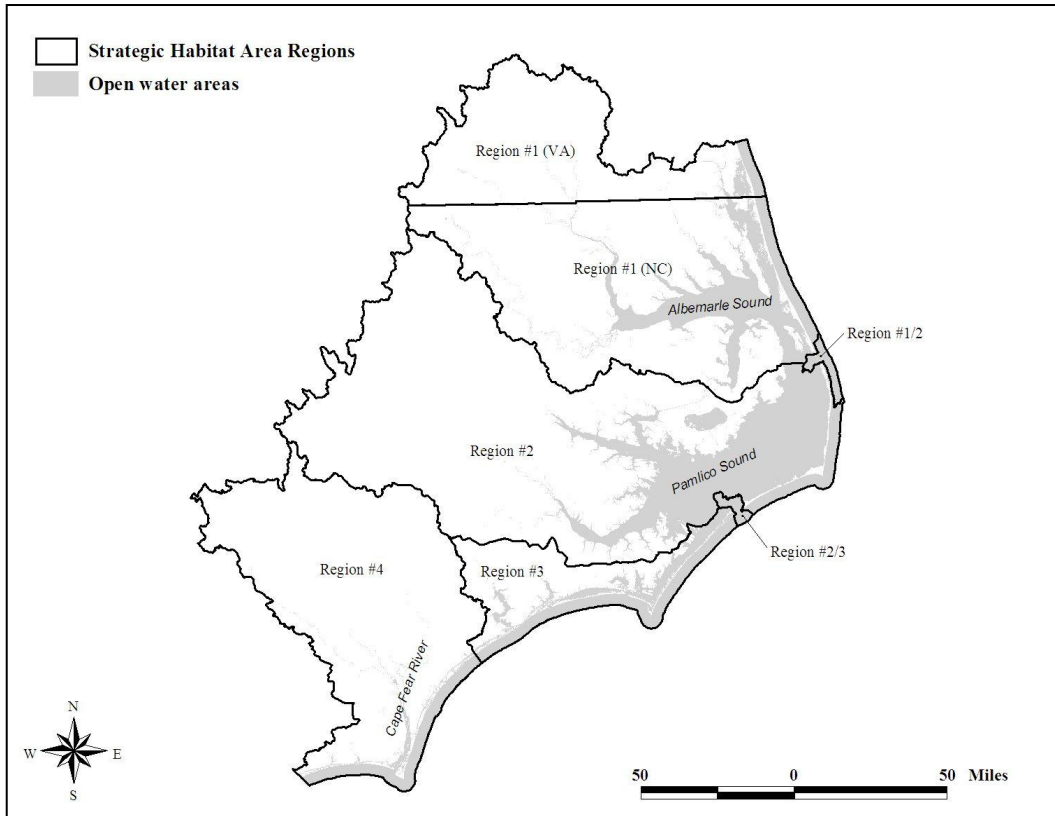
Map 2. Regional boundaries for Strategic Habitat Area nominations.

Region 2 includes the Neuse and Tar-Pamlico river basins and subbasin 03-01-55 of the Pasquotank river basin (northern Pamlico Sound). The Neuse and Tar-Pamlico comprise the third and fourth largest river basins in the state and both drain to Pamlico Sound. The Neuse river basin is more developed, with the towns of Raleigh, Goldsboro, Kinston, New Bern and Havelock within its watershed. Growth in the Neuse river basin is projected to increase 44% from 2000 to 2020. Major communities in the Tar-Pamlico include Rocky Mount, Greenville, and Washington. Closer to the coastline, extensive lowlands have limited land use to rural fishing and farming communities, such as Stumpy Point, Engelhard, Bellhaven, Swanquarter, and Merimon. On the Outer Banks, fishing and tourism are the primary businesses. Both the Neuse and Tar-Pamlico river basins are classified as Nutrient Sensitive Waters (NSW). The primary stressor is excess nutrient loading derived primarily from nonpoint runoff associated with agriculture and development, as well as point source discharges. There are a few large industries in Region 2 that may also contribute to water quality degradation, such as Domtar, PCS, and Cherry Point Marine Corps. Fortunately, Region 2 is rich in protected conservation lands, primarily in the lower estuarine and marine portion, which help offset impacts from other land uses. These include Alligator River NWR, Mattamuskeet NWR, Swanquarter NWR, Cedar Island NWR, Cape Hatteras National Seashore, and other conservation lands.

Region 2 is 5,942,938 total acres in size. However analysis was limited to a 'focus area', consisting of surface waters and a 500 m wide margin of shoreline. This area is 2,405,413 acres in size. Within the Region 2 focus area, all six habitat types identified in the CHPP are present, including water column, soft

bottom, shell bottom, submerged aquatic vegetation, wetlands and hard bottom (Street et al. 2005, Deaton et al. 2010). The Pamlico Sound area was chosen as the second regional assessment site due to the importance of the sound and rivers to North Carolina's fisheries, prominent fishery stocks with a concern or depleted status (i.e., oysters, blue crabs, southern flounder, spotted seatrout), and growing concerns regarding accelerated development in western Pamlico Sound and tributary shorelines, sometimes referred to as "Inner Banks" development.

In Pamlico Sound proper, the salinities generally range from 15-25 ppt and the shoreline is characterized by eroding salt/brackish marsh (Deaton et al. 2010). The flushing rate in the Pamlico Sound system is relatively low (over 200 days) compared to more riverine-dominated estuaries in North Carolina (Basta et al. 1990). The flushing rate is influenced by the relative areas of water to land (Region 2 over 20% water) in conjunction with lunar and wind tides. At locations relatively isolated from inlets, the wind tides can have a greater effect on flushing than lunar tides (Reed et al. 2004, 2008). Salinity and circulation patterns are the key physical conditions affecting the species composition occurring in juvenile nursery habitat in Pamlico Sound (Ross and Epperly 1985, Noble and Monroe 1991).

The Pamlico Sound system is well known as a major contributor of fish and shellfish in North Carolina, and an extremely important area for commercial and recreational fishing. While comprising approximately 56% of the state's total coastal waters, landings in Pamlico Sound contribute 32% of the total commercial landings in state waters, and approximately 7% of the reported recreational landings in 2009 (DMF 2010a). Of these, blue crab, brown and white shrimp, southern flounder, and striped mullet are among the top species landed commercially. Atlantic croaker, spot, bluefish, and spotted sea trout are common recreational species caught. Seasonal occurrence of sea turtles adds to the diversity of life that utilizes Pamlico Sound. The disproportionately high productivity of the Pamlico System may be attributed to the extensive riverine and estuarine wetland communities, shallow nursery areas, diversity of habitats and salinity regimes, and relatively low development. Pamlico Sound has long been regarded as the fishing gem of the North Carolina coast. The Division of Marine Fisheries considers the traditionally important priority fishery species of Region 2 to include American oysters, blue crab, Penaeid shrimp, southern flounder, red drum, and spotted seatrout (DMF Management Review Team, pers. com., 2011). Shad and striped bass are important anadromous fishery species in the upper rivers. Listed species, such as sea turtles and Atlantic sturgeon are also priorities for the region.

Habitat features that contribute to the integrity and exceptional productivity of the Pamlico Sound system include extensive SAV beds behind the Outer Banks and along the rivers, intertidal and subtidal oyster rocks, and Primary Nursery Areas (PNAs), (DMF Management Review Team, pers. com., 2011). Maintaining conditions to sustain and enhance these habitats is critical for management of the priority species of the region. The most pressing threat to water quality in Region 2 appears to be non-point source pollution from "Inner Banks" development and agricultural drainage. Loss of wetland shoreline edge from erosion and shoreline stabilization is a concern, particularly considering that the rate of sea level rise is predicted to increase to a point that may exceed the ability of wetlands to migrate landward and upward. The Region 2 SHA assessment focused on identifying areas that support the DMF identified priority fishery species and sites that incorporate the aforementioned habitats in their most unaltered state.

METHODOLOGY

A guidance document was developed to direct the methods for identifying SHAs (DMF 2006). The SHA identification process consists of three main phases, each of which requires input from a regional expert panel. The first phase in the SHA process is to identify priority species and/or habitats, and build a GIS database of existing biological and anthropogenic use data layers for Pamlico Sound. Once data is assembled by DMF staff, the regional expert panel for Region 2 reviews the data layers to ensure that they have sufficient spatial coverage and are current enough to be included in the SHA selection process. In the second phase, the panel examines the priority fish species for the region and sets the amounts of

each biological feature that the final SHA network should include. The second phase of the process is running the site selection software MARXAN (Ball et al. 2009) to determine an initial configuration of SHA networks. Once the MARXAN modeling is complete, the third phase consists of an expert committee reviewing the MARXAN selections and using corroborating information and their own ecological knowledge to modify the boundaries of the SHA network and derive a final network of SHA nominations.

IDENTIFICATION OF PRIORITY SPECIES

Pamlico Sound is a focal point for the oyster, crab, and shrimp fisheries, and is an important area for southern flounder, red drum, and spotted seatrout. The 2010 CHPP states "The areas that contribute most to the integrity of the system are a category of habitat termed Strategic Habitat Area." In a general sense, the abundance and diversity of habitat such as shallow nursery areas, SAV and oyster beds is what sustains Pamlico Sound productivity (Katy West/DMF, pers. com., 2011). The Region 2 SHA assessment focused on identifying areas that support the fisheries and habitats identified as priorities by DMF and the AC and those sites that incorporate the aforementioned habitats in their most unaltered state.

NATURAL RESOURCE TARGETS

In this analysis, "Natural resource targets (NRTs)" are defined as the habitats or ecological functions that represent essential or unique components of the fisheries ecosystem. NRT's vary by region and should be chosen to differentiate between habitats that are used differently by fish species. To do this, priority species were grouped into anadromous species, shellfish, winter spawning estuarine fish and summer spawning estuarine fish based on common life history strategies (Table 1). Each habitat target was evaluated based on its value to these species' groups to determine representation levels for the analysis. Once identified, the use of habitat by each group of priority species is documented and used to set representation levels (the amount of a habitat to be included in the SHA network). In addition to the importance to priority species, the contribution of a habitat as a buffer to improve water quality was also considered when setting representation levels. After an initial value was set, representation levels were also adjusted based on the regional importance of a habitat type, quality of habitat data, and overall amount of habitat in a region. A comprehensive list of NRT's and the chosen representation level are listed in Table 1.

Table 1. List of natural resource targets and representation levels used in the analysis.

CHPP habitat type	Natural Resource Target	Total Acres in Region 2	Representation level (%)	Importance to Priority Species				
				Anadromous fish	Shellfish	Winter spawning est. fish	Summer spawning est. fish	Contribution to water quality
Polygon habitat types								
Hard bottom	Riverine hard bottom	1,135	100	X				
SAV	High salinity SAV	89,854	70		X	X	X	X
	Low salinity SAV	1,751	100			X	X	X
Shell bottom	Intertidal shell bottom	66	100		X	X	X	X
	Subtidal shell bottom	3,717	100		X	X	X	X
Riverine soft bottom	Riverine - lowest	1,456	60	X				
	Riverine - lower	10,408	0					
	Riverine - middle	1,048	0					
	Riverine - upper	121	0					
Deep Soft Bottom	Estuarine (>6ft)	983,218	0			X		
	Marine (>6ft)	189,231	0			X		
Shallow Soft Bottom	Estuarine (0-3ft)	82,883	30		X	X	X	
	Estuarine (3-6ft)	78,259	20		X	X	X	
	Estuarine (ND)	2,457	10			X		
	Marine (0-3ft)	16,438	20			X	X	
	Marine (3-6ft)	15,386	20			X	X	
	Intertidal marine	451	20			X	X	
	Lacustrine (ND)	46,642	10	X		X		
	Palustrine (ND)	1,755	0					

Table 1 cont. List of natural resource targets and representation levels used in the analysis.

| CHPP habitat type | Natural Resource Target | Total Acres in Region 2 | Representation level (%) | Importance to Priority Species | | | | |
				Anadromous fish	Shellfish	Winter spawning est. fish	Summer spawning est. fish	Contribution to water quality
Polygon habitat types								
Wetland	Non-riparian	121,173	0					X
	Emergent (estuarine and riparian)	104,333	0					X
Wetland	Forested (estuarine and riparian)	138,788	10	X				X
	Estuarine shrub/scrub	12,175	0					X
	Headwater	5,735	50					X
Upland	Low elevation upland	47,944	20					
Ecological Designation	Primary Nursery Area	12,163	100			X	X	
TOTAL AREA		1,968,587						
Line habitat types (all distance values are in miles)								
Hard bottom	Ocean Hard Bottom	30	0					
Water column	Streams (high elevation)	46	0					
	Streams (low elevation)	1,061	20	X				
	Streams (mid elevation)	266	20	X				
Shoreline	Non-wetland shoreline	1,296	20			X	X	
	Wetland edge	2,921	50	X		X	X	X
Fish groups	River Fish Group	54,520				X	X	
	Sound Fish Group	32,403				X	X	

Hard bottom

Two types of hard bottom habitats occur in Region 2: riverine hard bottom and ocean hard bottom. Ocean hard bottom was delineated based on the Southeast Area Monitoring and Assessment Program's reef-dependent fish collections from the 1990s (SEAMAP 2001) and Moser and Taylor (1995). Presence of hard bottom habitat was inferred based on the presence reef fish species in trawl samples. The survey coverage and design prevented the creation of polygon features representing hard bottom habitat; therefore, ocean hard bottom is represented as line features. Because of the scarcity of the data, the inferential nature of the data collected, and lack of use of these habitats by priority species, the representation level for ocean hard bottom was set to zero; though it was assumed some would be chosen incidentally.

Riverine hard bottom (i.e., rocky outcroppings) was present in middle and upper elevation sections of the Neuse and Tar Rivers. The general boundaries of the rocky outcrops were described by WRC staff (B. Wynne, R. Barwick, V. Stancil, and C. Waters) and delineated by DMF staff for inclusion in the assessment. These areas are important spawning substrate for anadromous fishes of the region and are relatively rare, so the representation level was set to 100% for this habitat type.

Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation beds were mapped using aerial photography interpretation and transect data interpolation. Source data range in date of acquisition from the early 1980's to the very recent (Carroway and Priddy 1983; Ferguson and Wood 1994; ECSU 2002-2003-2006; DWQ 1998; DWQ 2005-2006-2007; DMF 1988-August 2009). With data up to 25 years old, significant changes in the distribution of SAV beds are likely to have occurred. Furthermore, the distribution of SAV habitat is likely more extensive than aerial observations suggest. For example, the growth of narrow fringing SAV beds and beds growing in organic stained water is difficult to discern from aerial photography (S. Chappell/DMF and J. Greene/DWQ, personal observation). Because of this, the extent of SAV habitat is likely underrepresented by the mapping data.

Mapped SAV was further differentiated into low (0-15 ppt) and high salinity (>15 ppt) beds, based on NOAA salinity classifications. Although SAV provides similar ecological services regardless of its location, salinity determines the fish species that are likely to be encountered in an SAV bed. Summertime measurements (which are considered the high salinity period) were used; therefore, the boundary helps capture the fluctuating boundary of both low and high salinity areas.

Large beds of high salinity SAV occur on the sound side of the outer banks. Such extensive beds of SAV are unique to region 2 and are important habitat for priority species. In addition, the presence of SAV indicates that water quality in an area is sufficient to support life, 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 (70%). Low salinity SAV is also important juvenile habitat for priority species, occupies less area, and is likely underrepresented in the data coverage since it is less visible in aerial photographs; therefore, the representation level was set to 100%.

Shell bottom

Shell bottom habitat in Region 2 was based on interpolated transect data collected by the DMF Bottom Mapping Program (DMF 1988-August 2009). The source data ranges from 1988 to August 2009, 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 Bottom Mapping Program.

Other sources of data were incorporated into the shell bottom target, including included cultch planting sites (DMF unpublished data, 1981-2008), historic Winslow-Ballance oyster reef footprints (Winslow 1889; Ballance 2004), oyster sanctuary boundaries (DMF unpublished data, 2010), and deep oyster reef profiles (USACE unpublished data, 2006-2007). The point data for cultch planting sites was converted to an area representing shell bottom based on the amount of cultch deployed (acres = bushels/8500). The additional shell bottom data was classified as subtidal shell bottom. Representation levels were set at 100% for both types of shell bottom habitat because they are regionally important as a resource and for maintaining water quality in Pamlico Sound.

Uplands

These areas were included because they are potential sites for marsh migration with sea level rise (Deaton et al. 2010). LIDAR elevation data (http://www.ncdot.org/it/gis/DataDistribution/ContourElevationData/, 2007) was used to delineate areas greater than 5 meters across adjacent to mapped NRT habitats less than 2ft above mean sea level. Non-wetland shorelines are also included in the category of uplands in the calculation of alteration scores. This linear target was created from the inverse of wetland shorelines selected by intersection the fishing water jurisdictions shoreline with the wetlands data. Both upland targets received a representation level of 20%. Non-wetland shoreline was assigned a representation level of 20% because these shorelines can be important habitat for some priority species.

Wetlands

Wetland targets were extracted from the NC Division of Coastal Management (DCM) wetland dataset (Sutter 1999). This dataset is a combination of National Wetland Inventory (NWI) maps (NWI 1981-1983), Natural Resource Conservation Service digital soil surveys, satellite imagery (1994) and hydrographic maps. Only contiguous wetlands within 90 meters of a stream or shoreline were included as a target for assessment. Wetlands of the following types are included in the region 2 analysis.

Estuarine/coastal wetlands
These wetlands are generally found along the margins of estuaries and sounds and sometimes exhibit tidal regimes. This group contains estuarine emergent wetland (salt/brackish marsh), estuarine shrub/scrub, and estuarine forest wetlands (including maritime swamp forests). Salt-brackish marsh occupy wetland areas at salinities from 0.5 to >35 ppt in North Carolina (Wiegert and Freeman 1990).

Riparian/riverine wetland
These wetlands are those in which hydrology is determined or heavily influenced by proximity to a perennial stream of any size or order. Overbank flow from the stream exerts considerable influence on their hydrology. The riverine or riparian wetlands (USACE mitigation type) include riparian emergent wetland (freshwater marsh) and riparian forested wetland (swamp forest and bottomland hardwood forests).

Non-riparian/flat-depressional wetland
These wetlands are generally not in direct proximity to surface water. While they may be either isolated from or hydrologically connected to surface water, the hydrology of depressional wetlands is primarily determined by groundwater discharge, overland runoff, and precipitation. The flat-depressional or non-riparian wetlands (USACE mitigation type) include non-riparian emergent wetland (freshwater marsh), non-riparian forested wetland (hardwood flat, pine flat, managed pineland), and non-riparian shrub/scrub wetland (pocosin).

Headwater wetland
These wetlands exist in the uppermost reaches of local watersheds upstream of perennial streams. Headwater systems may contain channels with intermittent flow, but the primary sources of water input are precipitation, overland runoff, and groundwater discharge rather than overbank flow from a stream.

Wetland edge
This target consists of the linear boundary of wetlands and open waters indicated on the fishing water jurisdiction coverage. The wetland edge target does not distinguish between marsh and forested edges. The inclusion of wetland edges was meant to minimize the selection of large areas of interior wetland (regardless of type), as well as capture an important ecotone within aquatic systems. Wetland shorelines are important habitats for juveniles of some priority species. Representation levels were set relatively high for the wetland edge target and lower for some wetland types under the assumption that those other riparian wetland habitat types would be captured with this target.

Wetlands were grouped into the following categories for the Region 2 analysis because they correspond to areas with similar usage by priority species: emergent wetland, forested wetland, headwater wetland, non-riparian wetland, and estuarine shrub/scrub wetland. Headwater and forested wetlands were assigned representation levels of 50 and 10 percent because of their function as spawning and nursery grounds for anadromous fish. Representation levels were not set for other wetland types, though it was assumed that adjacent wetlands would be captured as a function of wetland edge and other targets being met.

Creek/rivers and soft bottom habitats

Areas where there was no SAV, shell bottom, or other structured habitat were categorized as soft bottom or water column habitats. These targets were developed from a combination of DMF jurisdictional waters, NOAA bathymetric contour data, and National Wetland Inventory (NWI) open water classifications. Creeks and rivers are grouped under this heading because the process described here delineates riverine, estuarine, and marine systems for multiple targets. Creeks and rivers are considered a water column habitat for the purpose of alteration ratings because they have relatively high flushing rates compared to other soft bottom habitats.

The water column and soft bottom categories were further classified by system and depth category. The depth categories were 0-3ft, 3-6ft, >6 ft and no depth. These distinctions are important because they correspond to major differences in ecological function (i.e., shallow water nurseries). Depth data was derived from NOAA bathymetric charts (http://nauticalcharts.noaa.gov/mcd/Raster/Index.htm). The "no depth" category was assigned to channel-like hydrographic features adjoining more open waters, or where the bathymetric charts indicated no data. The delineation is valid where channel-like features are actually >3 ft deep. Unfortunately, these delineations may not have been consistently or completely applied. Soft bottom habitats are classified into riverine, lacustrine (lakes), estuarine, and marine systems.

- **Riverine** systems were separated from low salinity estuarine systems based on a linear or meandering morphology and a substantial (unditched) drainage network upstream.
- The **marine** system includes subtidal and intertidal waters of the coastal ocean and Oregon, Ocracoke and Hatteras Inlets hydrologic units.
- The **estuarine** system includes all open waters and intertidal flats between riverine and marine systems. The estuarine system also includes pond-like features surrounded by estuarine wetlands. Large tidal creeks, isolated marsh pools, and some estuarine open waters are currently lumped together. The no depth estuarine soft bottom NRT represented tidal creeks. The boundary of estuarine wetlands was also used to differentiating the estuarine and riverine systems.
- **Lacustrine** systems (lakes) were classified as such by NWI and larger than 15 acres. Only lakes connected to riverine or estuarine systems by linear water features were included. A 30 meter threshold was applied to determine connectedness of lakes to adjacent water features.

Estuarine and marine intertidal flats were defined as areas below the mean high water line indicated on the fishing water jurisdiction coverage (DMF, unpub. data 2004). Marine intertidal flats were classified by NWI as unconsolidated shores within the marine system. A narrow band of intertidal habitat along the Atlantic Ocean was assumed.

Marine systems were data poor regions for this analysis. Therefore, representation levels for marine systems were all set at 20% to capture a baseline amount of the ocean. Inlets were considered important because of their function in allowing migration in and out of the estuary, and were marked for inclusion in the final solution. Estuarine soft bottom is the most abundant target in the region. The shallower, nearshore areas were considered more important for fish species; therefore, representation levels were assigned proportional to depth group. Deep estuarine soft bottom was not assigned a representation level; the inclusion of a fish target provided the basis for selection of these areas. Riverine soft bottom habitat was further differentiated by position along the river (determined by elevation). The lowest category of riverine soft bottom habitat received a relatively high representation level because the corresponding areas are known overwintering grounds for important anadromous species. Other categories of riverine soft bottom were not considered especially important to any of the priority species groups and were therefore not targeted for consideration specifically in the SHA network; though a certain representation is assumed to be obtained incidentally in choosing adjacent targets.

Fish data

The inclusion of fish abundance data as a target was not possible in Region 1 due to the lack of adequate coverage by a survey with a stratified random survey design. In Region 2, trawl data (Program 195) from the deep waters of Pamlico Sound and the Neuse and Pamlico Rivers were used to identify a subset of areas within the deep soft bottom habitat of Pamlico Sound that might be of particular importance for fish abundance/productivity. Data from 1990- 2009 was used. Cluster analysis was used to divide resource species into two groups: one with higher abundance in the sound and one with higher abundance in the rivers (Figure 3a-b). Group abundance was summed for all species in a group at each survey point and averaged if more than one sample occurred in one geographic location. Kriging interpolation was used to create a surface of fish abundance for each group. Interpolated log of catch-per-unit-effort (CPUE) for each species group was assigned to hexagons that covered the main area of Pamlico Sound and the mouths of the Neuse and Pamlico Rivers. Details can be found in Appendix C (fish methods). Fish group representation levels were set at 20% for both fish groups, because they encompassed both summer and winter spawning estuarine fish groups.
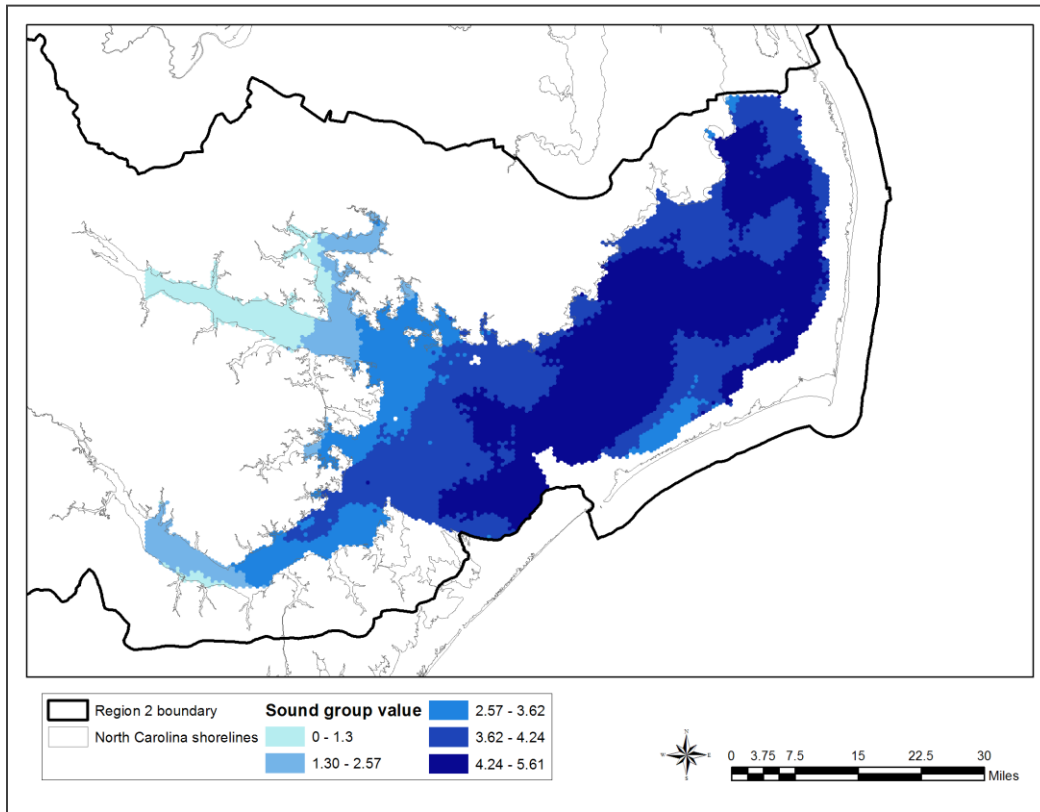
Map 3a. Summed catch per unit effort of fish in the sound grouping using Program 195 data.
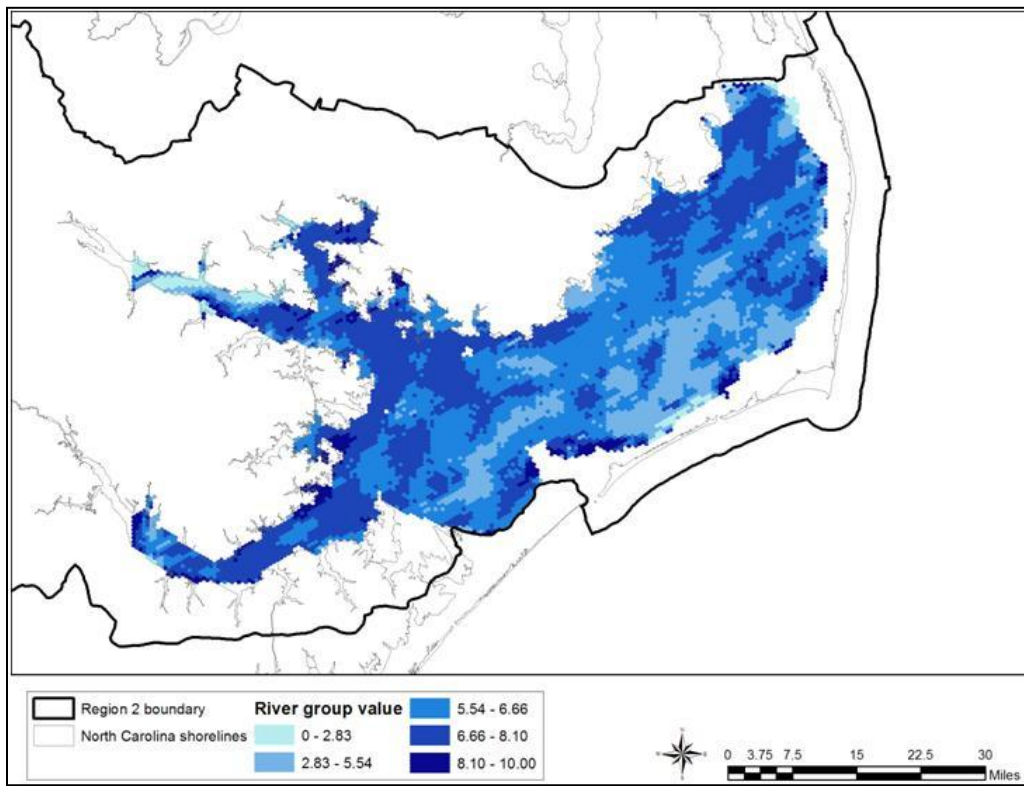
Map 3b. Summed catch per unit effort of fish in the river grouping using Program 195 data.

Streams

Small creeks and streams were represented using 1:100,000 scale data from the National Hydrologic Dataset (NHD), which 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. Finer scale NHD data was not available for the entire region and the coarser scale data represented larger streams that fish more frequently use.

There are three basic linear water features based on elevation (1 arc-second National Elevation Dataset). Stream order was not used because it was not readily available and much of region 2 has flat topography and highly ditched hydrology. Three elevation zones were set based on natural breaks occurring from sea level up to the fall line of riverine channels. We also considered differentiating swamp waters from other linear water features, but the classifications from DWQ were incomplete. In future analysis, it may be helpful to include stream orders for linear water features in the middle and upper zones, and a swamp water classification for streams in the lower zone.

Habitat complexes/functional areas

Primary Nursery Area designations were included in the analysis as a NRT. PNAs are specific areas designated based on juvenile abundance surveys of five different species (spot, croaker, southern flounder, brown shrimp and blue crab). The designation represents areas with relatively high juvenile fish abundance and represents a subset of highly productive nursery areas. All PNAs in Region 2 were identified as Strategic Habitat Areas for inclusion in the SHA network.

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 or listed species in this region include Atlantic sturgeon and sea turtles. Sturgeon habitat will be indirectly targeted through selection of riverine wetlands, streams, and soft and hard bottom. Green and loggerhead sea turtles are the most common listed species in Region 2. They tend to enter the sounds in the spring as they migrate north for the summer, and leave the sounds in the fall to migrate south for winter. Sea turtles are highly mobile, moving around as they feed opportunistically. Within Region 2, sea turtles are thought to be most abundant in eastern Pamlico Sound in water 10-20 ft deep, but can be found throughout the sound and lower rivers. Their habitat will be targeted indirectly through deep soft bottom and fish targets.

ALTERATION FACTORS

Alteration factors are human activities that impact the marine environment. The alteration factors used in the analysis are described in Table 2 and listed below. Factors included were evaluated for duplication with other factors. The advisory committee evaluated the data available on alteration factors and added some data that was not available in Region 1.

The natural resource targets of Region 2 were grouped into general habitat categories for the purpose of applying alteration factor ratings. For example, all wetland types are affected similarly by ditching and drainage; therefore, they form one habitat type for alteration. However, there were linear wetland features and polygon wetland features. In order to apply the equations presented in the SHA report (Appendix B), the linear features were converted into narrow polygon features. This conversion was also done for linear water features, unless noted below. The NRT groupings are listed and described below:

- 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
- Shell bottom – All categories of shell bottom

- <u>Soft bottom, deep</u> – All categories of estuarine and marine soft bottom >6ft deep. This category represents soft bottom under standing water conditions.
- <u>Soft bottom, shallow</u> – All categories of estuarine and marine soft bottom <6ft deep. This category represents soft bottom under standing water conditions.
- <u>Uplands</u> – Line features that were converted to polygons using a buffer 15 meters landward from non-wetland shorelines. The polygon target for low-elevation uplands was included in this basic habitat type for alteration.
- <u>Wetland</u> – Wetland edge was converted to polygons using a buffer 15 meters landward from wetland shorelines. Interior wetlands are polygon features >15 meters from wetland edge.
- <u>Streams</u> – Linear water column features converted to polygons using a 2.5 meter 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 2010 DWQ use support ratings, 2006 land cover data, stormwater outfalls, surface water intakes, silviculture operations, and beach nourishment. 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.

- Coastal Change Analysis Program (CCAP) 2006 land cover data was not available until after the total alteration layer was completed.

- Stormwater outfall maps from DWQ and DEH-SS&RWQ were incomplete for the region; the DWQ data covers only municipalities and the DEH data covers only SA water shorelines.

- The GIS data for water intakes was extremely outdated, excludes certain areas and intakes under large minimum thresholds, and the 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, the Advisory Committee felt the alterations to aquatic habitat were minor relative to other threats, and the activity was difficult to represent spatially (Deaton et al. 2010; Uphoff 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.

Table 2. Alteration factor ratings used in the current MARXAN analysis. Note: X means no overlap or does not apply.

CHPP habitat (NRT groupings)	Hydrology (water-based)								Water quality (land-based)											Physical (conversions)				
	Culvert obstructed	Water control structures	Impounded	Channelized streams	Vertical shoreline stabilization	Dredged channels	Ditched/drained	Canals & boat basin	Industrial waste pond	Major NPDES	Minor NPDES & aquaculture	Marinas (>10 slips)	Animal operation (major)	Animal operations (minor)	Mining discharge	Military targets/ordnance	Developed land-use	Agricultural land-use	Prohibited shellfish harvest	Bottom disturbing fishing gear	Wetlands lost to development[5]	Wetlands lost to agriculture[6]	Riparian upland development	Riparian upland agriculture
Creeks, rivers	X	1	2	1	X	X	X	1	X	2	1	1	1	0.5	1	X	2	2	1	X	X	X	X	X
SAV	0.5	1	2	X	X	3	X	2	X	2	1	2	2	1	1	1	2	2	1	2	X	X	X	X
Shell bottom	X	X	X	X	X	3	X	1	X	1	1	2	1	0.5	1	1	2	1	1	2	X	X	X	X
Soft bottom, deep	0.5	1	2	X	X	1	X	1	3	2	1	1	1	0.5	1	1	1	1	0.5	1	X	X	X	X
Soft bottom, shallow	0.5	1	2	1	X	2	X	1	3	2	1	2	1	0.5	1	1	1	1	0.5	X	X	X	X	X
Non-wetland shoreline[3]	0.5	1	2	1	2	X	X	X	X	X	X	X	X	X	0	X	1	1	0	X	X	X	2	1
Wetland, riparian[1]	0.5	1	2	2	2	X	X	X	X	X	X	X	X	X	0	X	0	0	0	X	3	2	X	X
Wetland, interior[2]	0.5	1	2	X	X	X	2	X	X	X	X	X	X	X	0	X	0	0	0	X	2	1	X	X
Streams[4]	0.5	1	2	1	X	X	2	X	X	3	2	X	2	1	1	X	2	2	0	X	X	X	X	X

[1] 15 meter landward buffer from wetland edge

[2] Wetlands >15 meters from wetland edge

[3] 15 meter landward buffer from non-wetland shoreline + low-elevation uplands

[4] 2.5 meter buffer around stream

[5] Includes land use classes low, medium, high, and open space development

[6] Includes land use classes cropland, pastureland, and barren

Alteration factors are loosely categorized as affecting hydrology, physical structure of habitat or water quality in an area. 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 channelized streams, dredged channels, ditched/drained, canals/boat basins, industrial waste pond, prohibited shellfish harvest, bottom disturbing fishing gear, habitats lost to development or agriculture, culverts and impoundments.
2. *Relative impact 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 a hydrologic unit and amount is relativized to the maximum value occurring in any hydrologic unit in the region. This includes vertical shoreline stabilization, NPDES, animal operations, aquaculture impacts, marinas, developed and agricultural land use, mining operations.

Hydrology alterations

Culverts
This factor identifies the watershed area (streams and wetlands) upstream from both documented and possible culvert location as altered. Altered areas were intersected with habitat present to identify altered areas. The culvert data was assembled from various sources, including Collier and Odum (1989), Moser and Terra (1999), and Department of Transportation (2003 data). In addition, possible culverts were located by creating a point where streams intersected roads with no bridge indicated on the DOT data.

Water control structures
This was applied to the stormwater gates around Lake Mattamuskeet (USFWS 2010). The designation was also applied to the dam on the Little River west of Goldsboro, which had breached, because the impacts were rated as similar by the advisory committee.

Impoundments
Impounded waters include all natural resource targets upstream from documented dam locations. The data sources for dam locations were Collier and Odum (1989), Moser and Terra (1999), Department of Transportation (2003 data), Division of Water Resources (2003 data), and USACE obstructions inventory (2009 data). The location of fish passage devices should be included and reviewed by appropriate committee members. Fish passage devices could make previously inaccessible waters partially accessible.

Channelized streams
Channelized streams are natural streambeds that were artificially straightened to enhance drainage and/or navigation. They differ from canals, which lack an original streambed and therefore, have little or no natural drainage. The specific location of channelization projects were visually estimated using the NHD for Region 2. Local Natural Resources Conservation Service (NRCS) staff was contacted, but no data was available (B. Chepuri/DMF, pers. com., 2010).

Vertical shoreline stabilization
Shoreline type data was extracted from the 1996 Environmental Sensitivity Index (ESI) maps produced by NOAA. Alteration was rated as the ratio of the linear distance of stabilized structures to the linear distance of shorelines in a watershed, scaled to the maximum in the region. Stabilized structures were defined as seawalls, corresponding to the ESI shoreline types of 'exposed rocky shores' and 'sheltered artificial structures'. Riprap was not included as a stabilization structure because it functions as fish habitat (Waters and Thomas 2001).

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

Ditched/Drained
Partially drained wetland areas were taken from the DCM wetland modifiers (applied to wetlands) and NHD ditched classification (applied to streams). The ditched classification was based on obvious linear and angular morphology. These data sources originated from the early 1990's. While this coverage has not been updated since the early 1990s, drainage projects in riparian wetlands have generally not been allowed since then so the data is likely pretty accurate.

Canals and boat basins
This alteration factor included obvious canals for navigation (very long and straight polygon features) or relatively short and straight, elongate polygons with no upstream hydrology (short, water access canals or boat basins). These features were digitized based on 1998 imagery and shoreline morphology. Some of the delineated boat basins could also overlap with marinas.

Water quality and land use alterations

Industrial waste ponds
This alteration factor was added to cover industrial waste pond located very close (<60 m) to other natural resource targets. The waste ponds were shown on the 1997 North Carolina Atlas and Gazetteer (Delorme 1997).

NPDES and aquaculture discharge
This factor was derived from NPDES sites locations provided by NCDWQ (2006 data). The impact of NPDES sites is difficult to quantify because the environmental impact of NPDES sites is variable and it is difficult to determine the area of influence for a point source without a detailed hydrologic model. We therefore decided to summarize NPDES sites by hydrologic unit to approximate the measure of alteration. NPDES sites are classified as major or minor based on the amount of discharge allowed per day. Sites discharging more than one million gallons per day were considered major. The number of major or minor NPDES within hydrologic units was then scaled by the maximum number occurring in the region, and the relative amount was used to calculate the relative severity of alteration. Note that major and minor NPDES were given different impact severities relative to habitat types (Table 2).

Current location and discharge data on large aquaculture operation was received from Division of Water Quality (A. Hodge/DWQ, pers. com., 2011.). Large aquaculture discharges were included with the minor NPDES factor because discharges from aquaculture facilities ranged from 54,236-435,363 gallons per day. However, aquaculture discharge is an untreated nutrient addition, and thus more concentrated than other minor NPDES.

Marinas
Wildlife Resources Commission and Shellfish Sanitation data on marina locations and slip numbers were combined to make one shapefile of all facilities with > 10 slips. The total number of slips at these facilities were aggregated per hydrologic unit and divided by the amount of shoreline (defined by the NRT wetland and non-wetland shoreline) in each hydrologic unit to create a slips/shoreline metric. This metric was scaled to the maximum value occurring in region 2, which was in Oriental (1021 slips; 0.012778 slips per meter of shoreline).

Animal operations
Locations and size of animal operations were obtained for poultry, swine and cattle operations. Swine and cattle operation information came from NC DENR's animal operations permits (DWQ, Non-

Discharge Compliance/Enforcement Section, available from NC Center for Geographic Information and Analysis on the internet at http://data.nconemap.com. Poultry data was downloaded from American Environmental Geographic Information System (AEGIS; available at http://www-geography.jsu.edu/ , downloaded 10/2009), which contains point locations of animal feeding operations identified through aerial photography. Each point location has an identifier giving the number of chicken houses at a site.

Animal operations were divided into major and minor based on the amount of nitrogen runoff generated by the operation. To do this, the amount of nitrogen production for each animal operation per year was calculated based on accepted values of nitrogen excreted per animal for each type of operation (McNaught et al. 2010). There are 554 swine operations, 3 cattle operations and 493 poultry operations in the study area. Values of nitrogen production per operation ranged from 0 to 470,274 lb N per year. The mean was 47,091; the distribution was heavily negatively skewed. The log-transformed distribution of N production is bimodal, with the mean of 9.5. This value was used to split animal operations into major (N production > 9.5) and minor (N production less than 9.5). All values greater than the mean were swine farms with the exception of one of the three cattle operations. Only one poultry farm is considered major, the rest are cattle and swine operations. The numbers of major and minor animal operations per hydrologic unit were calculated and the score for each hydrologic unit was scaled relative to the maximum number of each type of animal operation in region 2.

Mining discharge
Mining was included as an alteration factor because mining operations discharge fresh water into adjacent waterways. Freshwater discharge from mining operations was considered to have a low impact on soft bottom, shell bottom, SAV and water column habitats and received a rating of 1. Current data on mining discharge was acquired from the Division of Land Resources in August 2009. Location data was furnished with a column giving total acres in the mining operation. The impact of mine effluent on receiving hydrologic units was quantified using the acreage of the mining operation, under the assumption that the amount of water discharged was proportional to the size of the mining operation. To quantify the impact of mining discharge to adjacent habitats, the total acreage of mining operations in a hydrologic unit were summed. These values were then log transformed and scaled to the regional maximum (log value of 9.86) to get the relative extent for each hydrologic unit.

Military targets/ordnance
The military uses several areas in region 2 for training exercises, resulting in the accumulation of inactive ordnance at the site. Military designations in the area were considered an alteration because of anecdotal information regarding heavy metal contamination (A. Hodge/DWQ, pers. com., 2010). The alteration factor was rated low due to the mitigating effect of military areas as a refuge from trawling and a study finding no violations of EPA water quality standards in the areas (US Navy 2009). Several types of regulations exist in region 2, but only areas designated as prohibited and danger (no human entry allowed) were included in the alteration factor.

Developed land use
This factor was extracted from the 2001 National Land Cover Dataset using the low, medium and high intensity developed classifications. The total area of developed land-use within each 12-digit USGS hydrologic unit (HU) was calculated and scaled to the maximum proportion of developed land found in an HU in the region. A greater proportion of development within a HU suggests higher nutrient and chemical loadings from non-point development sources.

Agricultural land use
This factor was extracted from the 2001 National Land Cover Dataset using the cropland and pasture classifications. The total area of cropland within each 12-digit USGS hydrologic unit was calculated and scaled to the maximum proportion of developed land found in an HU in the region. A greater proportion of cropland within an HU suggests higher nutrient and chemical loadings from non-point agricultural sources.

Prohibited shellfish harvest
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 category of prohibited harvest are included; conditionally approved harvesting waters were not included because they are considered restorable by NC Department of Environmental Health - Shellfish Sanitation.

Physical disturbance

Trawling/dredging
The no trawling/no dredge coverage was created by DMF in accordance with 2004 MFC rules and provisions of the Shrimp Fisheries Management Plan (DMF 2006). Areas open to trawling or dredging and located in areas greater than 3ft deep were included in this alteration factor. Crab dredging areas were not included as 'no trawl' areas for the SHA process because dredging does not happen frequently or over a wide extent. The bottom disturbing gear factor was rated low in alteration because it represents only potential alteration within a very large area. Data on the frequency of trawling at specific locations is not available.

Converted wetlands
The area of wetland converted to other uses was incorporated as a metric of development in a region. This alteration factor was created by comparing wetland areas from the early 1990's (DCM data) to land use classifications from the 2001 National Land Cover data (NLC 2001) (30m resolution). The resulting maps show wetland areas that are now in some form of upland development, cropland, pastureland, or barren classification. The classifications for upland development included low, medium, high, and open space. The classifications for agriculture included cropland, pastureland, and barren. Cropland was only compared to forested wetlands because the classification accuracy differentiating salt marsh and cropland was low. Converted wetlands accurately reflect large shoreline developments where the shoreline has not greatly receded.

Converted uplands
This factor is specifically related to land uses within riparian upland areas. The land uses compared to converted wetlands were also used for converted upland shoreline. Similar to converted wetlands, converted upland shorelines accurately reflect large shoreline developments where the shoreline has not greatly receded. The land uses overlapping low elevation uplands were drawn from the CCAP 2006 dataset. The land use classifications for development included developed open space and various intensities of development. The land use classifications for agriculture include cultivated, pasture/hay, and bare land.

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 2). 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 2 was created using a combination of ArcGIS models and R scripts and is described in detail in APPENDIX B). The resulting alteration layer is shown in Map 4.
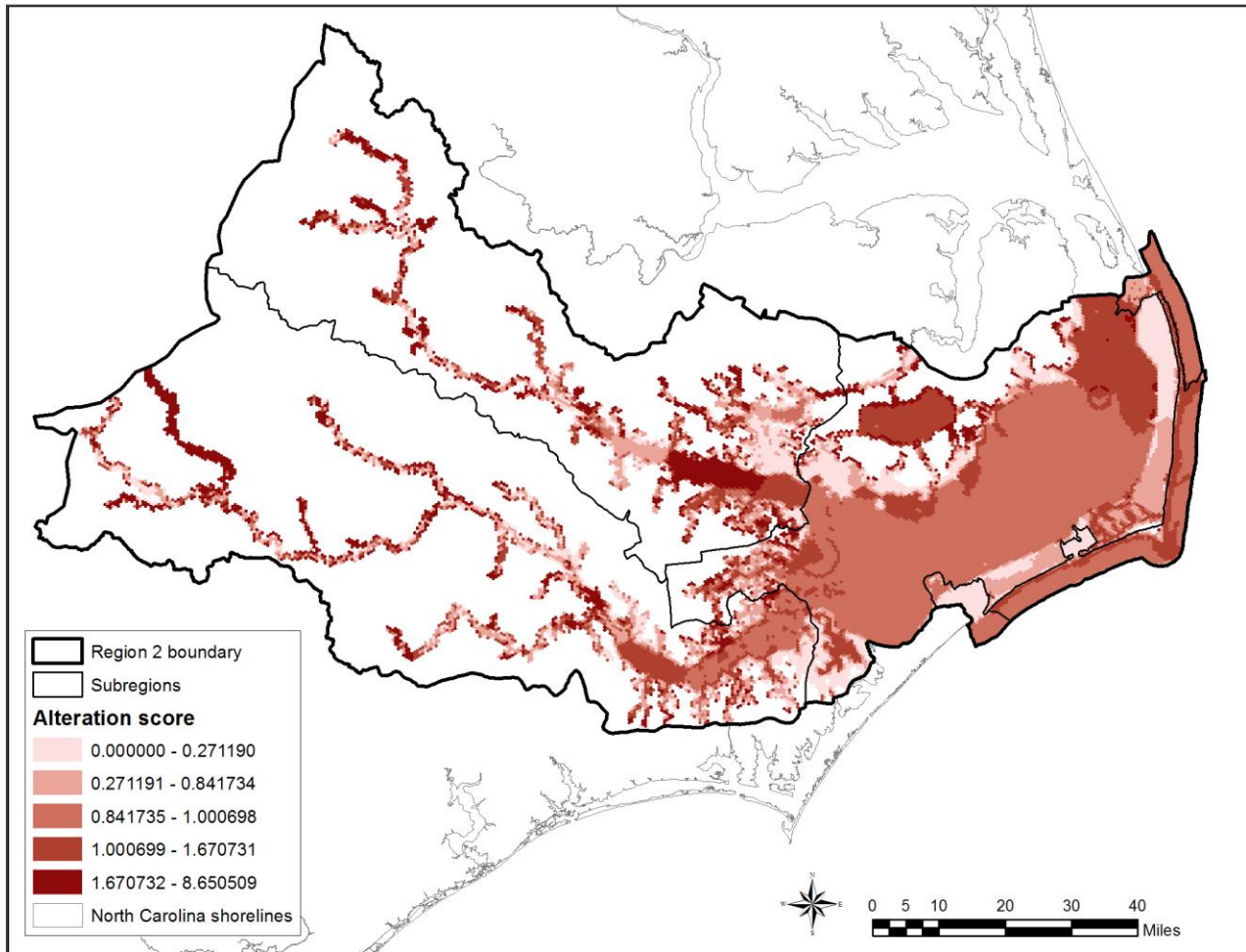
Map 4. Alteration layer for Region 2. Higher values equate to greater degradation.

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 a Duke University master's project (Smith 2005) and sequentially adopted as SHA methodology. The site-selection tool makes it possible to systematically consider multiple natural resource targets and various socio-economic factors represented as alterations. The computer 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 (e.g. 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. 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 124 acres in area, 880 m in diameter, and 440 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 a maximum amount 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. An informal sensitivity analysis was conducted for Region 2 (Appendix E), and it was decided to run each scenario for Region 2 500 times with 1,000,000 iterations per run. The BLM was adjusted to 0.001 in order to produce a solution which was driven by the difference in cost between runs. Lowering the BLM produced a solution that was relatively spatially aggregated in the rivers and along the shores of the sound, but resulted in many areas with three or fewer hexagons in Pamlico Sound. Areas composed of less than 3 adjacent hexagons were considered too small for management and removed from the solution considered in the corroboration stage. It was assumed that the advisory committee would add areas during the corroboration stage to make up for the area lost by eliminating these clusters.

Once preliminary areas are identified by MARXAN, SHA selections are modified and refined by a regional expert panel using other known sources of quantitative or qualitative ecological or fishery information and professional knowledge (referred to as corroborating data). Public input was required to finalize identification and nomination of areas for eventual SHA designation.

MARXAN RESULTS

After the natural resource targets and total alteration layer were assembled, MARXAN was run at the specified representation levels for targets representing priority fisheries habitats (Table 1). Map 5 depicts the MARXAN selections. This resulted in a lot of small random selections within the sound being selected. These areas appear to have been selected at low frequencies to meet the deep soft bottom and fish categories (Map 6). High selection frequencies are an indication that an area was not erroneously chosen. In looking at the selection frequencies, it is important to note that the inlets, riverine hard bottom, shell bottom, MFC designated PNAs, and overlapping selections from Region 1 were tagged for 100% selection. The amount of each target captured in the MARXAN solution is shown in Table 4. The initial MARXAN solution met the representation goals for SAV, riverine hard bottom, shell bottom, wetland edge, PNAs, and fish numbers. However it overselected forested wetlands, estuarine and marine soft bottom, low elevation streams, low elevation uplands, and non-wetland shoreline. A large amount of non-riparian, emergent, and estuarine shrub/scrub wetland were also included with the solution, although they were set for a 0% representation level. These wetlands were set to 0% purposely, knowing that they would be represented through the selections of wetland edge and additional capture due to occurrence within a 124 acre hexagon. Overall, the MARXAN solution resulted in 213, 888 acres (275%) of polygon targets being selected, and 1,949 mi (113%) of line targets being selected. Selections appear to be strongly influenced by proximity to the tagged targets.
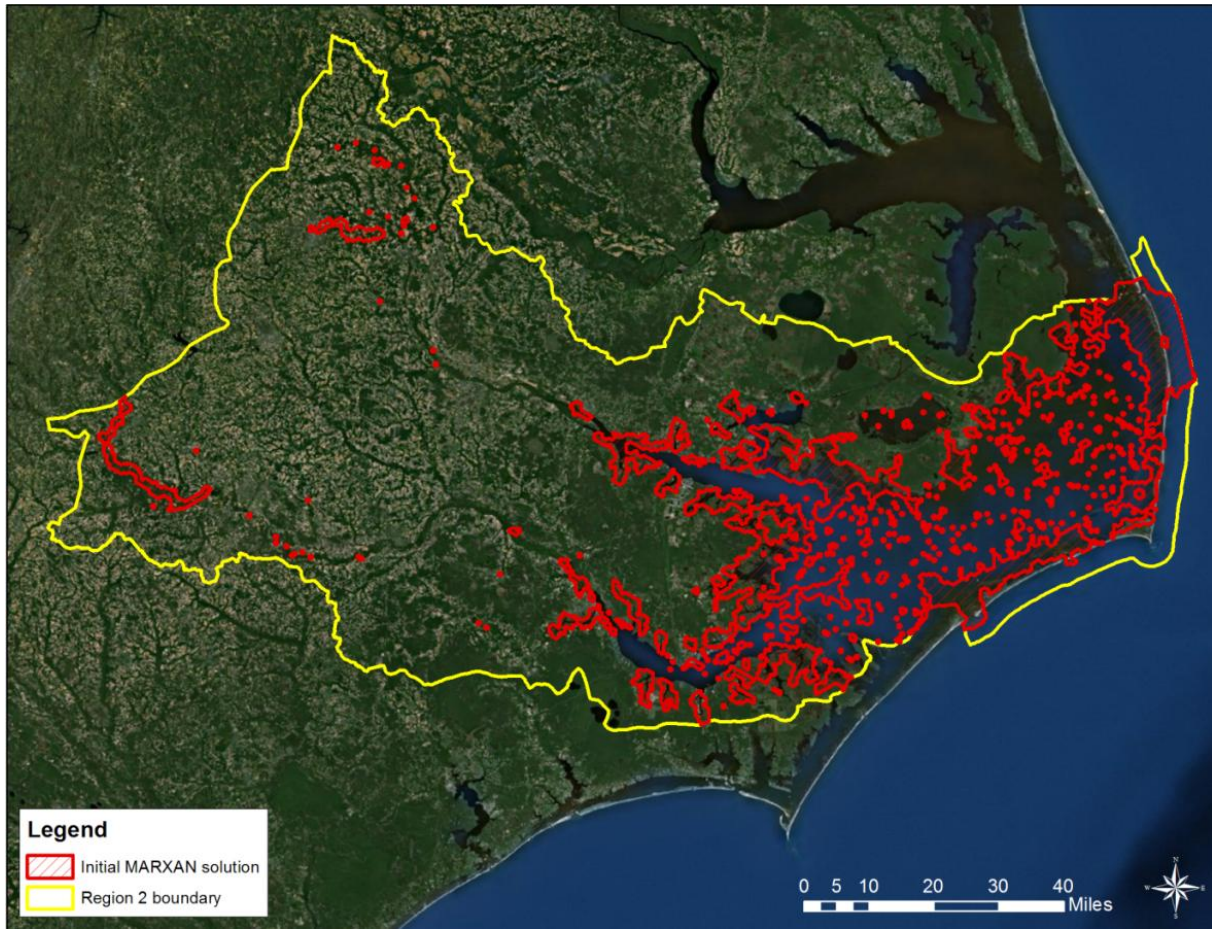
Map 5. MARXAN initial output.
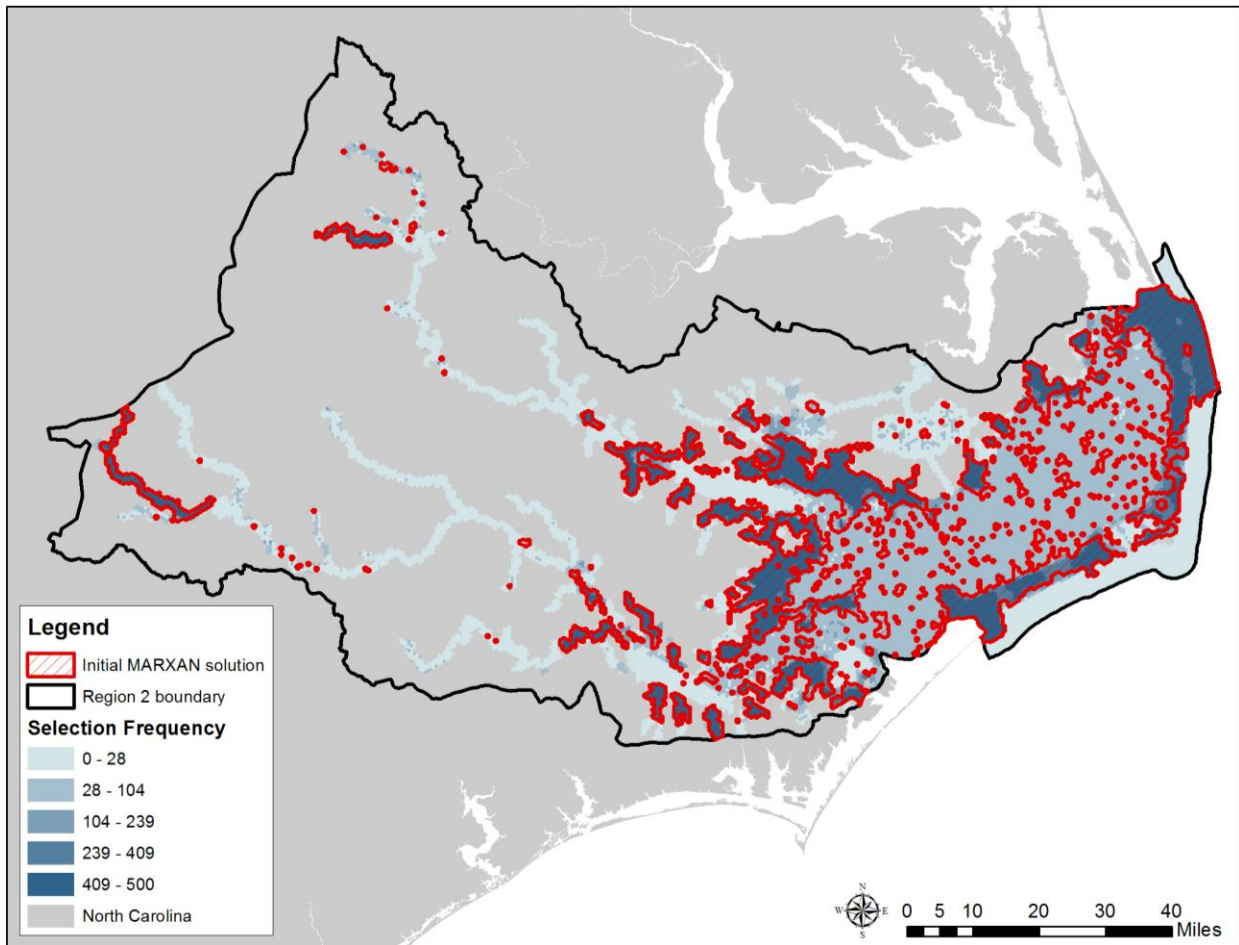
Map 6. Initial MARXAN results overlaid with selection frequency.

CORROBORATION

The committee spent two meetings reviewing the initial MARXAN selections and making expert modifications, as needed. The SHA committee grouped individual 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, the SHA committee reviewed data included within each polygon or group 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 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. Tables 4-7 and maps were used to review that information. The tables summarize information within the polygon, whereas the maps show spatially what is within and between the SHA selections.

Any modifications made were to be based on the following criteria:

- Habitats present – rare, vulnerable, diverse
- Occurrence of ecological designations
- Alteration factors and ratings
- Selection frequency
- Fish data/information available from DMF sampling or other research
- Fish abundance rank
- 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 3. 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 bay that was rated as altered but still supports fish production or an oyster rock 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.

The committee used the data presented in Tables 4-7 and the supporting appendix maps to cut, extend, and/or consolidate MARXAN clusters within the focus area. Selected hexagons with fewer than three contiguous hexagons were excluded. The majority of these was in Pamlico Sound and selected due to slightly higher fish abundance data. Consolidations were based on avoiding what the group considered over-represented habitats (i.e., soft bottom >6 ft) and connecting similar contiguous areas or under-represented habitats. Some natural resource targets were also clipped out of MARXAN polygons. For example, deep soft bottom areas were removed in some areas of the Neuse and Tar rivers and coastal ocean waters lacking hard bottom resources. The primary reason for excluding much of the riverine or estuarine soft bottom (>6ft) was to prevent over-representation of this resilient habitat. However, riverine soft bottom (>6ft) was included in historically important areas for anadromous fish.

Where MARXAN selections only included a portion of a habitat area (such as half of an SAV bed), the group assessed whether that cutoff point made ecological sense, and if not, extended the SHA boundary to include whole habitat units. MARXAN selections that included developed low elevation uplands were removed. The AC 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 in eastern Pamlico Sound, followed by western Pamlico Sound, Pamlico River, and Neuse River. Additional information and changes made to the selections were documented in Table 8.

Table 3. Ecological designations and biological data from DENR sampling programs that could be used as an indicator of aquatic habitat condition in Region 2.

Data type	Description	Data source/availability
Ecological designations	Anadromous Fish Spawning Areas	MFC designation
	Blue crab spawning sanctuaries	MFC designation
	Oyster sanctuaries	MFC designation
	Estuarine PNAs	MFC designation
	Inland PNAs	WRC designation
	Open shellfish harvesting waters	DEH-SS classification
	Significant Natural Heritage Areas (aquatic and terrestrial)	Natural Heritage Program designation
	Lands managed for conservation	One NC Naturally (DENR)
Species/ productivity data	Use support and biotic indices for fish and invertebrates (freshwater streams only) – index values	DWQ program
	Juvenile anadromous and freshwater fish	DMF program 100, 135
	Juvenile estuarine fish	DMF program 120, 915
	Adult estuarine fish	DMF program 195
	Shellfish densities	DMF program 635

OTHER CORROBORATING INFORMATION

Below is a partial list of written information that was provided by AC members and considered during corroboration. Complete citations are available in the Literature Cited section. Additional information in GIS format was also used.

Oyster larval dispersal:
Haase, A.T. 2009

Blue crab dispersal:
Eggleston D.B., N.B. Reyns, L.L. Etherington, G.R. Plaia, L. Xie. 2010.
Reyns, N.B., D.B. Eggleston, R.A. Luettich Jr. 2007.

Fish habitat utilization:
Spidel, M.R. 2009.
Smith, M.C. 2006.

Sea turtle distribution:
Keinath, J.A., J.A. Musik, and D.E. Barnard. 1996.
DMF. 2010b.

Military bombing ranges:
US Navy. 2009.
Sapp, Work, Haas, and Warren. 2010.

Sciaenid spawning activity:
 Luczkovich, J.J., Pullinger, R.C.; S.E. Johnson, M.W. Sprague. 2008.

Effect of development and agriculture on organisms:
Uphoff. 2008.
Meyer, Luczkovich, Brinson, and West. 2010.

Water quality:
DWQ. 2010 Tar-Pamlico Basinwide plan.
DWQ . 2008. Neuse River Basinwide plan.

POST-CORROBORATION RESULTS

Corroboration led to an overall increase in the area selected as SHA, with selected target polygon acres increasing from 213,888 acres to 322,843 acres. Targets that increased substantially included high salinity SAV, forested wetland, and estuarine soft bottom of all depths. Targets that decreased included intertidal shell bottom, non-riparian wetland, lacustrine soft bottom, and low elevation uplands. After the AC completed the modifications, there were 67 discrete areas selected for nomination, totaling 631,820 acres of hexagons. This comprises 26% of the focus area or 10% of the total area within Region 2. Of that selected acreage, 308,545 acres and 1,924 miles consist of habitat targets. (Note that the acreage of PNAs was subtracted from the subtotal since PNA acreage is also accounted for the individual habitat targets). Acreage of selected targets is included in Table 4. Of the 308,545 acres selected for SHA nomination, 82% consist of submerged non-shoreline targets, and 18% consist of wetland or upland targets that may be adjacent to privately owned land (18% of 308,545 acres = 55,538 acres). Map 7 and 8 show the selection frequency and alteration scores of the post-corroboration SHAs. The majority of the areas that were not initially selected by MARXAN but were added by the AC had low selection frequency but low to medium alteration scores.
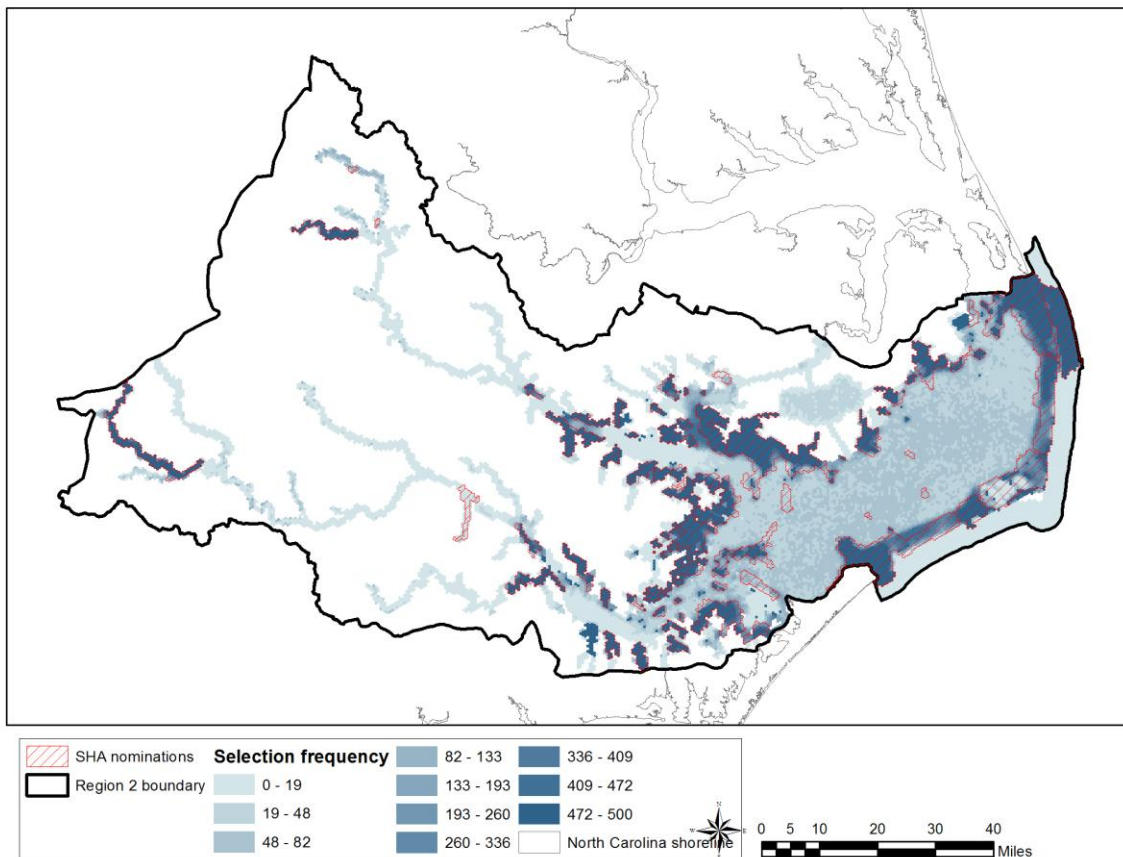
Map 7. SHA nominations after corroboration showing selection frequencies.
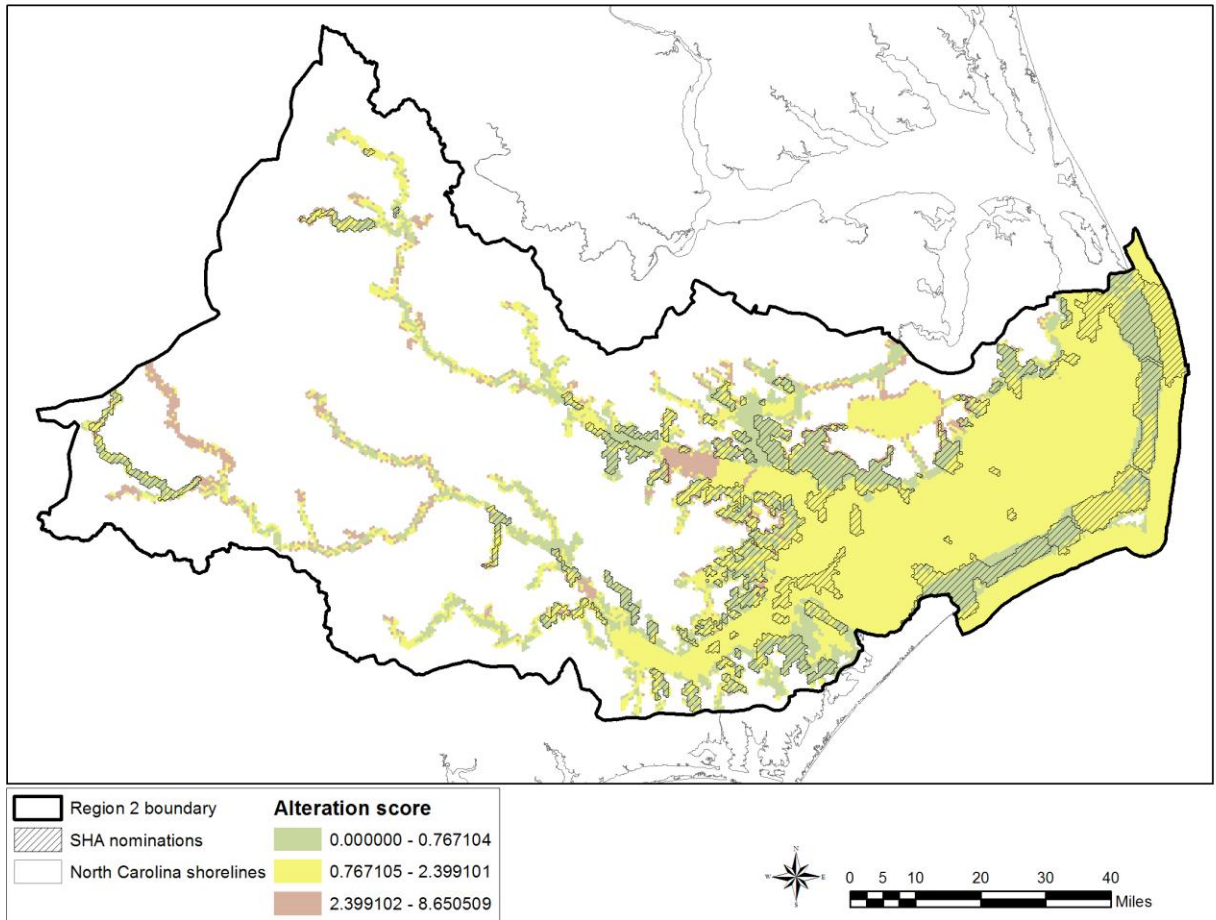
Map 8. Alteration score of post-corroboration SHA nominations. Management goals – target lowest scores (green) SHAs for protection/conservation, mid scores (yellow) for protection/enhancement, and highest scores (pink) SHAs for restoration.

The final SHA selections form a network of priority areas for protection and enhancement ranging from the upstream watersheds of the Pamlico system to the grass beds and ebb tide deltas of the Outer Banks. Selections were concentrated along the eastern Pamlico Sound shoreline, lower estuary and upper headwaters of the Neuse and Pamlico rivers. Almost all of the high salinity SAV along the Outer Banks and low salinity SAV along the river tributaries was selected. The AC considered this appropriate since it is a critical habitat for the majority of the priority species, is a unique habitat feature of North Carolina that is known to contribute significantly to the diversity of fish life in the region, and is a habitat easily lost from physical disturbance (dredging) or water quality degradation. Along the Outer Banks, input from DMF staff indicated that fish and invertebrates were fairly uniformly distributed within the SAV, with no one area being more productive or higher quality than another, except possibly the grass beds in closest proximity to the inlets, since they can be the first structured habitat larval and juvenile fish encounter as they move in from the ocean. All mapped riverine hard bottom and some other upper areas of the Neuse and Tar were selected due to their importance as spawning areas for anadromous fish species. A few areas along the rivers were also selected. One area that was added through corroboration was Core, Village and Kidney creeks. WRC had documented that this area was one of the only areas on the Neuse or Tar-Pamlico that blueback herring were utilizing on a fairly consistent basis for spawning. Setting the representation level of PNAs at 100% encouraged MARXAN selection of other nearby targets, many of which were emergent or forested wetlands, and also soft bottom and shell bottom. The

PNAs are located in small bays and tidal creeks of the lower Neuse and Pamlico rivers and western Pamlico Sound shoreline. Concentrating SHAs around existing PNAs provides a buffer of protection and connectivity for juvenile fish movement to other estuarine habitats. Shell bottom was also set with high representation levels due to their ecological and fishery importance in the area, and current low abundance due to historical losses. Almost all mapped subtidal shell bottom was selected (95%), and approximately 75% of the intertidal oysters. SHAs selected over open water were due to occurrence of subtidal shell bottom, high fish abundance of river and sound groups, or a combination of both shell and fish. The mouths of the Neuse and Pamlico rivers appear particularly important for this.

Region 2 has an abundance of state and federally protected lands bordering coastal waters (Table 7, Maps 9a-b). Of the 631,820 acres of selected hexagons, 9% (58,701 a) occur on lands managed for conservation (state, federal, local), and 2% (14,298 a) are located in MFC designated PNAs. Some of the larger conservation lands on the western side of Pamlico Sound include Alligator River NWR, Swanquarter NWR, Cedar Island NWR, and Goose Creek Game Land, which together provide protection of low lying wetlands and water quality, particularly along the lower Neuse, Pamlico, and western Pamlico Sound shorelines. Much of the eastern side of Pamlico Sound is within Cape Hatteras National Seashore or Pea Island National Wildlife Refuge. SHAs within protected conservation lands are basically already protected from degradation associated with development. The remaining 88% (558,821 a) represent SHA nominations of various condition that are currently vulnerable to land and/or water based threats.
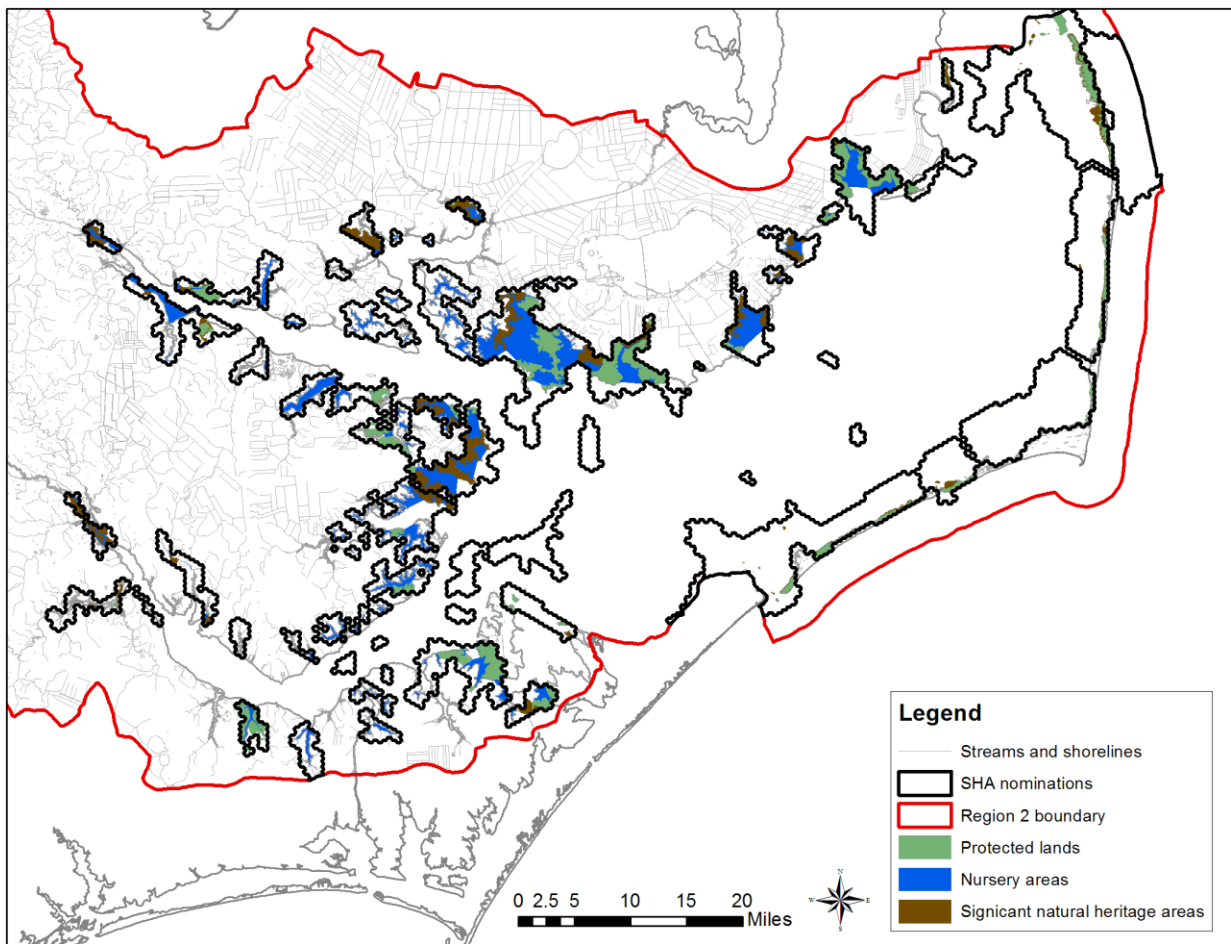
Map 9a. Post-corroboration SHA nominations, noting occurrence of state, federal, and private (land trust) conservation lands and MFC designated PNAs. Eastern portion of Region 2.

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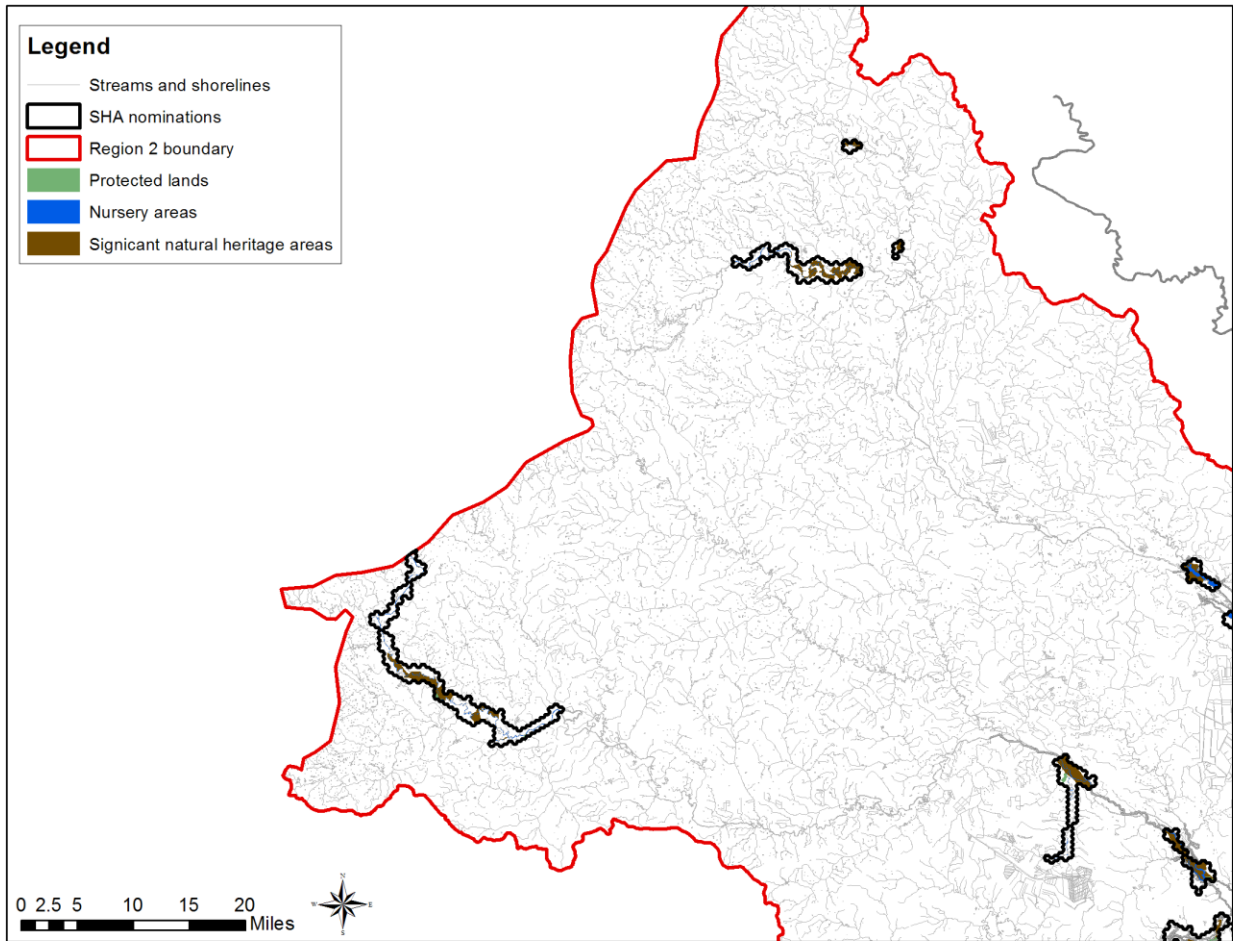
Map 9b. Post-corroboration SHA nominations, noting occurrence of state, federal, and private (land trust) conservation lands and MFC designated PNAs. Western portion of Region 2.

FINALIZING STRATEGIC HABITAT AREA POLYGONS

The SHA committee grouped individual selected hexagons into manageable polygons for the corroboration and identification process. The SHA committee also examined maps of both the selection frequency and alteration ratings for guidance during the manual selection phase. For each polygon or cluster of contiguous polygons, the SHA committee reviewed data included within each polygon or cluster to confirm inclusion/exclusion as a SHA in a consistent and data based manner. This included examination of the alteration scores, selection frequencies, habitat diversity and rarity, supporting biological data, and connectivity with adjacent selections and protected area. Tables 5-7 and maps were used to review that information. The tables summarize information within the cluster, whereas the maps show spatially what is within and between the clusters.

Table 4. Representation levels, target acres, and resulting amounts of natural resource targets.*

	Natural Resource Target Type	Acres in study area	Representation Level	Target Acres	Amount captured by MARXAN	% of target met	Amount selected after corroboration	% of target met
Hard Bottom	Riverine hard bottom	1,135	100	1,135	1,135	100	1,135	100
SAV	High salinity SAV	89,854	70	62,898	61,987	99	86,161	137
	Low salinity SAV	1,751	100	1,751	1,721	98	1,670	95
Shell Bottom	Intertidal shell bottom	66	100	66	64	97	49	74
	Subtidal shell bottom	3,717	100	3,717	3,593	97	3,540	95
Wetland	Non-riparian wetland	121,173	0	0	44,301		38,998	
	Emergent wetland	104,333	0	0	65,395		65,710	
	Forested wetland	138,788	10	13,879	25,688	185	27,109	195
	Estuarine shrub/scrub wetland	12,175	0	0	6,489		6,953	
	Headwater wetland	5,735	50	2,867	2,754	96	2,318	81
Riverine soft bottom	Riverine soft bottom - lowest elev.	1,456	60	874	872	100	783	90
	Riverine soft bottom - lower elev.	10,408	0	0	2,300		2,406	
	Riverine soft bottom – mid. elev.	1,048	0	0	7		7	
	Riverine soft bottom - upper elev.	121	0	0	0		0	
Shallow Soft Bottom	Estuarine soft bottom (0-3ft)	82,883	30	24,865	44,993	181	48,304	194
	Estuarine soft bottom (3-6ft)	78,259	20	15,652	37,786	241	43,430	277
	Estuarine soft bottom (ND)	2,457	10	246	1,589	647	1,725	702
	Marine soft bottom (0-3ft)	16,438	20	3,288	12,232	372	12,588	383
	Marine soft bottom (3-6ft)	15,386	20	3,077	12,678	412	12,693	412
	Intertidal marine soft bottom	451	20	90	451	500	451	500
	Lacustrine soft bottom (ND)	46,642	10	4,664	3,548	76	1,646	35
	Inlets		100	earmarked				
	Palustrine soft bottom (ND)	1,755	0	0	383		347	
Deep Soft Bottom	Estuarine soft bottom (>6ft)	983,218	0	0	13,904		118,556	
	Marine soft bottom (>6ft)	189,231	0	0	50,428		50,530	
Eco-desig	PNA	15,426	100	15,426	15,384	100	14,298	93
Upland	Low elevation upland	47,944	20	9,589	17,333	181	15,079	157
POLYGON TOTALS (acres)		1,493,124		77,770	213,888	275	322,843	415
Line targets	Wetland edge	2,921	50	1,461	1,428	98	1,467	100
	Non-wetland shoreline	1,296	20	259	521	201	457	176
	Ocean Hard Bottom	30	0	0	9		9	
	Streams (high elevation)	46	0	0	5		5	
	Streams (low elevation)	1,061	10	106	173	163	171	161
	Streams (middle elevation)	266	20	53	40	75	40	75
LINE TOTALS (miles)		4,217		1,720	1,949	113	1,924	112
Fish (numbers)	River Fish Group	54,520	20	10,904	9,893	91	8,954	82
	Sound Fish Group	32,403	20	6,481	5,371	83	4,798	74

*Gray boxes are target selections that exceeded the representation levels.

Table 5a. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number									
	1	2	4	7	14	15	17	19	20	21
Polygon Area	870	621	10,191	60,403	15,163	4,847	2,610	1,367	5,344	1,367
Mean alteration	1.52	0.63	1.17	0.63	0.45	0.67	0.46	1.94	1.30	0.36
Mean selection frequency	82	38	485	424	417	407	43	490	406	483
Emergent wetland				1,749	3,099	1,045	1,084	250	1,080	532
Estuarine shrub/scrub wetland				606	901	139	39	69	93	26
Estuarine soft bottom (>6ft)				13,348	2,976	258	248	146	1,028	
Estuarine soft bottom (3-6ft)				5,027	2,994	329	122	38	268	19
Estuarine soft bottom (ND)							263		0	
Estuarine soft bottom (0-3ft)				4,381	2,387	412	283	182	1,008	541
Forested wetland	329	165	1,470	46		268	163		44	
Headwater wetland										
High salinity SAV				18,744	0					
Intertidal marine soft bottom				451						
Intertidal shell bottom				13						0
Lacustrine soft bottom (ND)			21	748						
Low elevation upland				412	29	455	171	524	667	0
Low salinity SAV										
Marine soft bottom (>6ft)				4,054						
Marine soft bottom (3-6ft)				3,872						
Marine soft bottom (0-3ft)				4,280						
Non-riparian wetland	13	3	41	91	2,660	1,556	61	152	1,058	185
Palustrine soft bottom (ND)		1	20	26	2	0	7		2	
PNA					304			87	697	66
Riparian human impacted wetland			19							
Riverine hard bottom			366							
Riverine soft bottom (ND) - lower		18	2			88			11	
Riverine soft bottom (ND) - lowest										
Riverine soft bottom (ND) - middle										
Riverine soft bottom (ND) - upper										
Subtidal shell bottom				428	111	117		0	1	63

Table 5b. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number									
	27	38	40	41	42	43	44	47	49	51
Polygon Area	870	4,971	1,491	621	4,723	2,486	3,977	13,796	10,813	21,626
Mean alteration	1.00	0.81	0.96	0.80	0.32	0.89	0.87	0.53	0.71	0.97
Mean selection frequency	52	377	473	500	482	414	490	485	445	457
Emergent wetland		405	64	93	169	52	36	32	2,596	3,298
Estuarine shrub/scrub wetland		52	4		353		16	10	294	378
Estuarine soft bottom (>6ft)	870	2,656		52	92	1	347	2,197	3,452	2,248
Estuarine soft bottom (3-6ft)		649	110	81	232	0	258	881	2,211	1,520
Estuarine soft bottom (ND)			165						0	307
Estuarine soft bottom (0-3ft)		915	66	159	399		329	500	1,122	2,180
Forested wetland			55	3	666	1,225	394	1,101		211
Headwater wetland					132		10	9		156
High salinity SAV									4	
Intertidal marine soft bottom										
Intertidal shell bottom		11								
Lacustrine soft bottom (ND)										368
Low elevation upland			110	135	356	47	72	267	553	683
Low salinity SAV			0		22	1	4	489		142
Marine soft bottom (>6ft)										
Marine soft bottom (3-6ft)										
Marine soft bottom (0-3ft)										
Non-riparian wetland		106	39	15	385		72	88	359	2,510
Palustrine soft bottom (ND)		1		1		1	4	8	21	29
PNA				47	42		882		642	583
Riparian human impacted wetland				0	15	15		3		302
Riverine hard bottom										
Riverine soft bottom (ND) - lower			53			190	28	65	37	2
Riverine soft bottom (ND) - lowest						628		45		
Riverine soft bottom (ND) - middle										
Riverine soft bottom (ND) - upper										
Subtidal shell bottom		176	23	9					103	

Table 5c. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number									
	52	54	57	59	60	61	65	68	69	70
Polygon Area	60,900	870	497	1,119	17,276	4,101	4,474	39,274	5,096	18,891
Mean alteration	0.49	1.88	1.00	1.00	0.30	1.30	1.00	0.90	0.90	0.87
Mean selection frequency	410	500	61	57	495	500	46	194	424	425
Emergent wetland	17,629	83			2,500	159		576	1,876	5,547
Estuarine shrub/scrub wetland	335	34			196	51		144	90	250
Estuarine soft bottom (>6ft)	19,299	34	497	1,119	2,542	127	4,474	7,377	444	4,354
Estuarine soft bottom (3-6ft)	6,555	90			1,068	412		6,144	786	3,323
Estuarine soft bottom (ND)	286					17				210
Estuarine soft bottom (0-3ft)	6,729	165			2,432	339		2,001	596	2,877
Forested wetland	50	22			117	413			1	
Headwater wetland	24				26	1				
High salinity SAV	23				11			22,292	394	100
Intertidal marine soft bottom										
Intertidal shell bottom								10		
Lacustrine soft bottom (ND)						6			132	89
Low elevation upland	1,520	39			2,400	127		127		
Low salinity SAV		0			170	23				
Marine soft bottom (>6ft)								29		
Marine soft bottom (3-6ft)								38		
Marine soft bottom (0-3ft)								103		
Non-riparian wetland	6,293	215			5,005	500		15	347	1,412
Palustrine soft bottom (ND)	79				6	3		1		8
PNA	2,511	126			941	69			367	900
Riparian human impacted wetland									384	174
Riverine hard bottom										
Riverine soft bottom (ND) - lower	34					60				
Riverine soft bottom (ND) - lowest										
Riverine soft bottom (ND) - middle										
Riverine soft bottom (ND) - upper										
Subtidal shell bottom	1,386				167			84	1	326

Table 5d. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number									
	71	74	78	81	82	83	86	91	93	96
Polygon Area	7,582	12,304	20,383	1,243	621	4,474	11,683	1,740	7,581	7,333
Mean alteration		0.26	0.83	1.31	0.93	0.65	1.01	1.01	1.12	0.69
Mean selection frequency		450	471	500	471	400	281	313	468	78
Emergent wetland		81	3,905	131	44	264			259	637
Estuarine shrub/scrub wetland		75	346	25						73
Estuarine soft bottom (>6ft)		1,865	4,472	70			11,614	1,725	237	3,273
Estuarine soft bottom (3-6ft)		99	1,467	50	2				139	1,342
Estuarine soft bottom (ND)			61						5	
Estuarine soft bottom (0-3ft)		382	3,268	141	36				110	1,538
Forested wetland	2,946		80	9	25	2,114			1,445	
Headwater wetland			40			53			11	
High salinity SAV		3,555	575	0	0					449
Intertidal marine soft bottom										
Intertidal shell bottom		1								
Lacustrine soft bottom (ND)			170			58			13	
Low elevation upland	6	4	954	115	74	374			237	3
Low salinity SAV						17			342	
Marine soft bottom (>6ft)		1,780								
Marine soft bottom (3-6ft)		1,691								
Marine soft bottom (0-3ft)		2,468								
Non-riparian wetland	17	13	2,355	4	70	114			90	1
Palustrine soft bottom (ND)	5		2	1		0			15	2
PNA			1,574	98	30					
Riparian human impacted wetland	2		58	1		2			12	
Riverine hard bottom										
Riverine soft bottom (ND) - lower	213					639			767	
Riverine soft bottom (ND) - lowest	35					62				
Riverine soft bottom (ND) - middle										
Riverine soft bottom (ND) - upper										
Subtidal shell bottom		0	100				69	15		

Table 5e. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number 97	98	99	100	102	104	105	106	107	109
Polygon Area	20,756	2,610	1,491	5,966	621	1,864	1,616	746	5,220	3,853
Mean alteration	0.31	0.50	1.30	0.95	1.01	0.64	1.01	0.21	0.08	0.73
Mean selection frequency	408	500	500	499	431	293	386	362	358	492
Emergent wetland	7,140	151		403		168		48	2,504	505
Estuarine shrub/scrub wetland	761			23		9		5	115	70
Estuarine soft bottom (>6ft)	2,739		568	6	617	19	1,592		162	71
Estuarine soft bottom (3-6ft)	1,544	129	89	234		186			208	299
Estuarine soft bottom (ND)									112	
Estuarine soft bottom (0-3ft)	2,469	121	30	701		164		51	305	324
Forested wetland	180	115	1	264		105		75	7	144
Headwater wetland	1,126							29	23	163
High salinity SAV	49			9		0			235	2
Intertidal marine soft bottom										
Intertidal shell bottom										
Lacustrine soft bottom (ND)										
Low elevation upland	512	87	5	271		64		19	46	528
Low salinity SAV		32	190			5				
Marine soft bottom (>6ft)										
Marine soft bottom (3-6ft)										
Marine soft bottom (0-3ft)										
Non-riparian wetland	2,709	101		367		56		44	1,384	990
Palustrine soft bottom (ND)	3	0						1		5
PNA	489	8		620		4		25	117	334
Riparian human impacted wetland										
Riverine hard bottom										
Riverine soft bottom (ND) - lower		9				26				
Riverine soft bottom (ND) - lowest						12				
Riverine soft bottom (ND) - middle										
Riverine soft bottom (ND) - upper										
Subtidal shell bottom	41			0	4		24		0	0

Table 5f. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number								
	110	112	113	115	123	128	130	134	136
Polygon Area	2,983	4,971	5,841	56,550	36,167	2,113	8,451	7,954	8,079
Mean alteration	0.84	0.66	0.59	0.40	0.96	0.46	0.83	0.23	0.77
Mean selection frequency	491	500	488	391	490	471	490	454	452
Emergent wetland	214	153	217	1,016	35	70	552	588	1,217
Estuarine shrub/scrub wetland		14	3	347	46	16	125	19	122
Estuarine soft bottom (>6ft)	199		75	10,237		367	273	39	694
Estuarine soft bottom (3-6ft)	182	150	250	1,931		96	356	78	315
Estuarine soft bottom (ND)		110	4					44	140
Estuarine soft bottom (0-3ft)	361	304	315	2,902		309	893	44	1,455
Forested wetland	93	294	302			21	307	1,577	144
Headwater wetland	34	67	69			32	215	82	11
High salinity SAV	1			12,859					39
Intertidal marine soft bottom									
Intertidal shell bottom				10					
Lacustrine soft bottom (ND)					8				
Low elevation upland	214	194	147	85	104	273	704	167	728
Low salinity SAV		29	1			1	165	37	
Marine soft bottom (>6ft)				12,168	32,490				
Marine soft bottom (3-6ft)				6,718	343				
Marine soft bottom (0-3ft)				5,099	466				
Non-riparian wetland	153	174	489	4	15	643	3,025	1,279	963
Palustrine soft bottom (ND)			1				13	8	1
PNA	183	534	297			166	576		913
Riparian human impacted wetland	2	4					6	74	163
Riverine hard bottom									
Riverine soft bottom (ND) - lower			0					162	
Riverine soft bottom (ND) - lowest			0						
Riverine soft bottom (ND) - middle									
Riverine soft bottom (ND) - upper									
Subtidal shell bottom	2			151		23	0		1

Table 5g. Alteration scores, selection frequencies, and amounts of targets within selected SHA polygons.

Parameter	Polygon number							
	137	140	144	145	147	148	149	150
Polygon Area	6,339	22,371	497	31,941	373	249	124	2,859
Mean alteration	1.02	0.73	0.87	0.60	0.56	0.91	1.51	0.65
Mean selection frequency	330	477	500	354	500	500	500	89
Emergent wetland		129	26	949	43	148	26	131
Estuarine shrub/scrub wetland				432		41		204
Estuarine soft bottom (>6ft)	6,226		51	498	78		14	584
Estuarine soft bottom (3-6ft)			14	681	23	6	38	403
Estuarine soft bottom (ND)								
Estuarine soft bottom (0-3ft)			50	679	62	46	20	1,219
Forested wetland		10,110	7		3		0	
Headwater wetland		6						
High salinity SAV			8	26,812				
Intertidal marine soft bottom								
Intertidal shell bottom				4				
Lacustrine soft bottom (ND)		34						
Low elevation upland			20	380	60	0	12	
Low salinity SAV					1			
Marine soft bottom (>6ft)				9				
Marine soft bottom (3-6ft)				31				
Marine soft bottom (0-3ft)				171				
Non-riparian wetland		197	96	55	91	6		317
Palustrine soft bottom (ND)		62		9				
PNA			27		12	14	13	
Riparian human impacted wetland		34						
Riverine hard bottom		769						
Riverine soft bottom (ND) - lower								
Riverine soft bottom (ND) - lowest								
Riverine soft bottom (ND) - middle		7						
Riverine soft bottom (ND) - upper								
Subtidal shell bottom	113			1				

Table 6a. Proportion of ecological designations contained within selected SHA polygons.

Polygon ID	Area	Inland PNA	Primary Nursery Area	Secondary Nursery Area	Anadromous fish spawning area	Crab spawning sanctuary	Oyster Sanctuary	Artificial Reef	Outstanding Resource Waters	Significant Natural Heritage Area _A	Significant Natural Heritage Area _B	Significant Natural Heritage Area _C
1	870				0.71					0.71	0.86	
2	621				0.40					0.40		0.80
4	10,191	0.70			0.72					0.72		0.61
7	60,403					0.15	0.00			0.13	0.03	
14	15,163		0.25	0.39						0.07		0.61
15	4,847											0.62
17	2,610			0.67							0.71	0.38
19	1,367		0.82									0.55
20	5,344		0.70		0.02							0.51
21	1,367		0.27									0.91
27	870											
38	4,971											0.28
40	1,491											
41	621		1.00									
42	4,723	0.13		0.24	0.21						0.58	
43	2,486	0.80		0.20	0.35					0.15		0.75
44	3,977	0.81										
47	13,796			0.31	0.06							0.18
49	10,813		0.40	0.51	0.01						0.51	
51	21,626	0.14	0.17	0.09							0.23	
52	60,900		0.37	0.42	0.00		0.00		0.38	0.36	0.24	
54	870	1.00										
57	497											
59	1,119											
60	17,276		0.60	0.12								
61	4,101	0.12			0.06					0.03		
65	4,474								0.03			
68	39,274						0.00			0.00		
69	5,096		0.66	0.51							0.80	
70	18,891		0.38	0.53			0.01				0.69	
71	7,582	0.38									0.39	
74	12,304					0.44					0.06	0.08
78	20,383		0.60	0.26							0.13	
81	1,243		1.00									
82	621		0.80									

Table 6b. Proportion of ecological designations contained within selected SHA polygons.

Polygon ID	Area	Inland PNA	Primary Nursery Area	Secondary Nursery Area	Anadromous fish spawning area	Crab spawning sanctuary	Oyster Sanctuary	Artificial Reef	Outstanding Resource Waters	Significant Natural Heritage Area_A	Significant Natural Heritage Area_B	Significant Natural Heritage Area_C
83	4,474				0.61					0.17	0.83	
86	11,683											
91	1,740											
93	7,581										0.05	0.13
96	7,333										0.27	0.07
97	20,756		0.23				0.01				0.22	
98	2,610		0.05		0.14							
99	1,491											
100	5,966		0.88	0.08	0.25							
102	621											
104	1,864		0.13	0.27	0.13							
105	1,616											
106	746		0.33									
107	5,220		0.14							0.40	0.31	
109	3,853		0.81									
110	2,983		0.75	0.08								
112	4,971	0.85										0.05
113	5,841		0.60	0.23								
115	56,550					0.20	0.00		0.14	0.04	0.10	
123	36,167							0.00		0.06		
128	2,113	0.47										
130	8,451	0.07	0.66	0.07								
134	7,954			0.06	0.11						0.06	0.02
136	8,079		0.77	0.25								
137	6,339											
140	22,371	0.61			0.64					0.02	0.34	0.05
144	497		1.00									
145	31,941										0.14	
147	373		1.00									
148	249		1.00								1.00	
149	124		1.00									
150	2,859											0.52

Table 7a. Acres of state and federal conservation lands within selected SHA polygons.

Polygon ID	Acres of overlap
4	**36**
Upper Coastal Plain Research Station (State)	36
7	**4,495**
Cape Hatteras National Seashore (Federal)	885
Pea Island National Wildlife Refuge (Federal)	3,553
WRC Island C 05-06 (State)	56
14	**6,431**
Alligator River National Wildlife Refuge (Federal)	5,258
Dare County Air Force Range (Federal)	23
Gull Rock Game Land (State)	1,150
17	**81**
Pungo River Game Land (State)	81
21	**732**
Gull Rock Game Land (State)	732
38	**613**
Alligator River National Wildlife Refuge (Federal)	613
42	**1,526**
Goose Creek (State)	1,526
43	**5**
North Carolina Estuarium (Local)	5
44	**8**
Historic Bath State Historic Site (State)	8
47	**630**
Nevil's Creek (Land Trust)	516
Nevil's Creek (CLT) Preserve (Private)	115
49	**574**
Gull Rock Game Land (State)	574
51	**3,382**
Goose Creek Game Land (State)	3,382
52	**18,205**
Gull Rock Game Land (State)	595
Mattamuskeet National Wildlife Refuge (Federal)	3
Swanquarter National Wildlife Refuge - Swanquarter Wilderness (Federal)	4,696
Swanquarter National Wildlife Refuge (Federal)	12,911
68	**350**
Buxton Woods Coastal Reserve (State)	0
Cape Hatteras National Seashore (Federal)	350
69	**390**
Goose Creek Game Land (State)	390

Table 7b. Acres of state and federal conservation lands within selected SHA polygons.

Polygon ID	Acres of overlap
70	**2278.90**
(Land Trust)	8.75
Goose Creek Game Land (State)	784.06
Hobucken Marshes (CLT) Preserve (Private)	12.51
Prohibited - near Brant Island (Federal - Navy)	1473.58
74	**629.90**
Cape Hatteras National Seashore (Federal)	629.90
78	**556.15**
(Land Trust)	69.90
Hobucken Marshes (CLT) Preserve (Private)	53.91
Lampe-Woodard Tract (Land Trust)	432.34
83	**111.60**
Bellair Plantation (CLT) Preserve (Private)	13.94
Bellair Plantation (Land Trust)	16.49
Neuse River Game Land (State)	81.17
87	**3.17**
Neuse River Game Land (State)	3.17
93	**75.38**
Brices Creek (Land Trust)	61.31
Croatan National Forest (Federal)	9.45
Sawmill (NCDOT) Wetland Mitigation Site (State)	4.62
96	**704.99**
Cedar Island National Wildlife Refuge (Federal)	160.72
Marine Corps Air Station Cherry Point - Piney Island (Federal)	444.71
Prohibited - vicinity of Piney Island (Federal - Navy)	99.56
97	**5218.38**
Carteret County Game Land (State)	1420.35
Marine Corps Air Station Cherry Point - Piney Island (Federal)	3372.81
Prohibited - vicinity of Piney Island (Federal - Navy)	309.47
Turnagain Bay (CLT) Preserve (Private)	115.75
107	**1341.55**
Cedar Island National Wildlife Refuge (Federal)	1341.55
112	**3475.31**
Croatan National Forest (Federal)	1379.52
Marine Corps Air Station Cherry Point - Main Air Station (Federal)	1542.26
Restricted - vicinity of Cherry Point (Federal - Navy)	553.53
113	**224.03**
Croatan National Forest (Federal)	224.03

Table 7c. Acres of state and federal conservation lands within selected SHA polygons.

Polygon ID	Acres of overlap
115	**2637.02**
Cape Hatteras National Seashore (Federal)	2572.17
Cape Lookout National Seashore (Federal)	64.85
123	**456.77**
Cape Hatteras National Seashore (Federal)	40.83
Pea Island National Wildlife Refuge (Federal)	415.94
134	**27.63**
Neuse River Game Land (State)	27.63
136	**750.70**
(Conservation Group)	750.70
140	**420.77**
(Land Trust)	35.13
Howell Woods (Other Public)	189.97
Howell Woods Environmental Learning Center (State)	189.95
Montgomery Laurel Bluffs (TLC) Preserve (Private)	2.86
Popular Creek Bluffs (Land Trust)	2.86
145	**1620.24**
Cape Hatteras National Seashore (Federal)	1620.24
148	**203.88**
Gull Rock Game Land (State)	203.88
(blank)	
(blank)	
71	**143.08**
Core Creek (Land Trust)	143.08
150	**364.08**
Alligator River National Wildlife Refuge (Federal)	364.08
Grand Total	**58701.16**

Table 8a. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID	Change	Ecological Reason
All	add any PNAs not selected by MARXAN	selected 100%
All	remove hexagons with developed low elevation uplands with no targets	
3-Jan	keep as is	
4	combine with 5 - now 4	
5-7	keep as is	
8	extend to include all SAV	
9	delete	
10	keep, add to 38	
11	join to 122	productive shell bottom
12	delete	Stumpy Bay - not as productive as other areas to the south
13	join to 122	productive shell bottom- oyster sanc
14	keep	Long Shoal River
15	eliminate Bellhaven (1 hex)	developed
16	combine with 140	
17	add up river to campground and tribs	unique brackish marsh
18	delete	Mattamuskeet, not good for blue crab
19	keep	Middleton Anchorage
20	add 3 hex to include Charles Rock?	Far Creek and productive oyster bottom
21-22	keep	natural rock
23-26	delete	
27	change to fit shoal	
28-37	delete	
38	combine with 10	
39	keep	
40	eliminate Jack's Creek	Jacks -bad habitat, no shellfish. Pungo Creek good
41	keep	
42	eliminate 4 hex of ag, expand west to get east side of Broad Creek	
43	eliminate hex over Washngton	Chocowinity, includes downtown Washngton, good striper fishing
44	exclude Back Creek, trim developed hex	Bath Creek, muddy, detrital, developed, low DO
45	combine with 140	
46	delete	developed shoreline
47-48	keep as is	47-48 - AFSA
49	keep, connect to Mattemuskeet - up to flapgates	
50	make part of 140	
51	remove mitigation ponds, add Little creek and main part of South Creek	51-57 - productive PNAs, NCPC tract?
52	extend to include areas of high fish abundance	
53	keep	
54	trim to IPNA, eliminate Bayview	
55	keep as is	
56	keep as is	lots of SAV
57	keep as is	boaters guide shows wreck
58	reduced in size (cut fingers) and combined with Ocracoke	
59	remove 2 hex, clip to fit shoal	

Table 8b. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID	Change	Ecological Reason
58	reduced in size (cut fingers) and combined with Ocracoke	
59	remove 2 hex, clip to fit shoal	
60	keep as is	
61	eliminate PCS, trimmed SE corner	
62	combine with 140	
63	add 13 hex S to oyster reef. Rose Bay to almost Brandt Island Shoal	record level of oysters 2010-11. Last 2 seasons - Dermo, not this year
64	delete	
65	join with 77, label as 65	Upper Middle Ground
66	add snowed creek & remove 3 polygons of impoundment	
67	keep as is	hammock island - diverse- Reid
68	removed Buxton, keep rest	diverse
69	remove impoundment hexs without stream edges	
70 - 71	keep as is	
72	delete	
73	remove impoundment on west side, fix hole in feature	
74	include Hatteras point (NPS)	
75	delete	
76	combine with 86 & label as 86	
77	join with 65- label 65	Upper Middle Ground
78	trim XS	Vandemere, heavily fished
79	combine with 90	
80	delete	
81	keep as is	
82	remove 5 hex on west side, clip to creek, split into 2 & rename E	
83	keep as is	
84-85	delete	fish only
86	add 76 to 86	
87	keep as is	
88	add adjacent creek from 82, cut significantly, remove inland hex	
89	combine with Ocracoke	
90	combine with 79	
91	keep	good drum fishing & oysters
92	delete	
93	remove 3 hex - no targets; add 1 hex to get entire river	
94	keep	
95	delete	not priority habitat
96	add point to the west (tip of land) to wetland edge	pristine, Raccoon Island - cultch oysters, better than West Bay
97	keep	little development, canal into Turnagain - good fishing
98	keep	Beard's Creek, SAV, eels

Table 8c. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID	Change	Ecological Reason
99	remove 8 hex, New Bern, ponds, interchange	hi altered, but SAV present
100	exclude Oriental, trim to remove excess hex, split into 2	
101	remove hex with airport	
102	keep	
103	delete	no PNA, altered, ferry route
104	trim west and extend main branch to Neuse R	Dawson's Creek, no hardened shoreline, better than adj creeks
105	keep	oysters, tarpon, drum
106	keep	
107	exclude ditches, remove SE portion to exclude canal, keep creek next to it - good for Flounder	quality marshes, drains Open Grounds
108-109	keep	
110	2 polys out, cut in half (no way to cut out water without excluding shore	Adams Creek, SNA
111	delete - Slocum Creek	sediment contamination, no benthos, mullet, stripers
112	Hancock Creek - keep, eliminate 1 hex that's not hydrologically connected	speckled trout, red drum, IPNA
113	keep	good shrimping
114	keep, re-examine with Region 3	intertidal oysters
115	extend to shoreline, add SAV and wetlands	
116	delete everything north of ferry	
117	combine with 74 - Hatteras Inlet	
118	combine with 74 - Hatteras Inlet	
119	delete - combine with OBX SAV	also artificial reef
120	connected both parts, cut boundary b/t 120 & 68 at Avon channel - combine with 8. all SAV, excluding channels	to exclude navigation channel
121	delete	
122	add 11 & 13 to 122	productive, Crab Hole, shell bottom ~ 12 ft deep, crab trawling/dredging allowed
123	keep - R1 selection	
124	delete - Stumpy Bay	silty
125	cut off 2 hex	
126	add 2 hex on E side & 8 on W side of island, add marsh on W side - Straits b/t 126 & Great Island & bay W of Great Island	good oyster habitat
127	remove open water, cut farms	open water no different than surrounding areas; includes artificial reef
128	trim small polys	Jordan Creek
129	remove open water	
130	keep	good system - North Creek
131	cut deep water river crossing	Blounts Bay
132	remove 1 open water hex	
133	keep	
134	keep	Goose Creek

Table 8d. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID	Change	Ecological Reason
135	add 1 hex to river, remove from mouth, remove NW creek, west part, exclude area w/ houses and ramp	ramp, shrimp trawling
136	eliminate developed/farm areas; split into smaller by length, keep impoundments, add shoreline	were mapped as wetlands but weren't
137	trim to oyster bed	136 &137 red drum hot spot
138	add shoreline around mouth	SAV and good fish habitat
139	keep	
140	add 16, 50, 45, 62	includes Neuse River hard bottom
141	included adj creek hex	no wetlands upstream
142	combine with 4	
143-145	no change	
146	Duck Creek - added then removed	
147	added - Flax Pond	PNA
150	added shoreline north of Stumpy Pt Bay	Eggleston - important blue crab settlement area under certain weather conditions

FINAL STRATEGIC HABITAT AREA NOMINATIONS

Based on public comments received at the October 11, 2011 public meeting (Appendix F), no changes were made to the proposed SHAs, with the exception of a slight modification of boundaries within SHA # 93 to exclude a section of urbanized shoreline in New Bern. The MFC approved the SHA nominations at their November 3, 2011 meeting. Strategic Habitat Area units are described below (numbering is not sequential) beginning in the Outer Banks and moving counter-clockwise around the region. Strategic Habitat Areas with average alteration scores less than 1.0 and selection frequencies greater than 300 (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 following is a list of final SHA nominations grouped by region. Maps 10.1 through 10.20 follow showing the location of each SHA.

OUTER BANKS

SHA #115: Ocracoke Inlet system (Map 10.1)

Description – Ocracoke Inlet, flats, banks, and channels behind the inlet – Ocracoke Island
Acres – 56,550
Prominent habitats – High salinity SAV, inlet, shallow and deep estuarine and marine soft bottom, emergent wetlands, intertidal shell bottom, subtidal shell bottom
Ecological designations – CSS, SNHA, ORW
Conservation Lands – Cape Hatteras National Seashore
Fish data – yes
Prominent alterations present – some residential/seasonal development (Ocracoke), multi-slip docking, trawling
Avg. total alteration score – 0.63
Avg. selection frequency – 424

SHA #57: Pamlico Sound Fish Area 1(Map 10.1)

Description – good fish data, inside of Ocracoke Inlet
Acres – 497
Prominent habitats – estuarine soft bottom > 6 ft, good fish data
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present –
Avg. total alteration score – 1.0
Avg. selection frequency – 61

SHA #74: Hatteras Inlet system (Map 10.2)

Description – Hatteras Inlet, flats, banks, and channels behind the inlet – Hatteras area, Hatteras village excluded
Acres – 12,304
Prominent habitats – High salinity SAV, inlet, intertidal flats, shallow and deep estuarine soft bottom
Ecological designations – CSS, SNHA
Conservation Lands – Cape Hatteras National Seashore
Fish data – yes
Prominent alterations present – some multi-slip docking, trawling, residential development (Hatteras), trawling
Avg. total alteration score – 0.26
Avg. selection frequency – 450

SHA #59: Pamlico Sound Fish Area 2 (Map 10.2)

Description –good fish data, inside of Hatteras Inlet
Acres – 1,119
Prominent habitats – marine soft bottom, good fish data
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present – trawling
Avg. total alteration score – 1.00
Avg. selection frequency – 57

SHA #68: Eastern Pamlico Sound, behind Cape Hatteras (Map 10.3)

Description – grass flats, shallow bottom behind the Outer Banks, Buxton – Frisco area
Acres – 39,274
Prominent habitats – High salinity SAV, soft bottom < 6 ft, emergent wetlands, intertidal shell bottom, subtidal shell bottom
Ecological designations –
Conservation Lands – Cape Hatteras National Seashore, Buxton Woods Coastal Reserve
Fish data – yes
Prominent alterations present – minimal, some marinas, residential development (Buxton and Frisco), trawling
Avg. total alteration score – 0.09
Avg. selection frequency – 194

SHA #145: Eastern Pamlico Sound, northern Hatteras Island (Map 10.4)

Description – high salinity SAV, shallow bottom behind the Outer Banks, Rodanthe, Waves, Salvo, Avon area
Acres – 31,941
Prominent habitats – High salinity SAV, shallow soft bottom < 6ft, emergent wetlands
Ecological designations – SNHA, CSS
Conservation Lands – Cape Hatteras National Seashore
Fish data – yes
Prominent alterations present – residential and seasonal development (Salvo, Avon), trawling
Avg. total alteration score –0.60
Avg. selection frequency – 354

SHA #7: Oregon Inlet system (Map 10.5)

Description – Oregon Inlet, flats, banks, and channels behind the inlet (Oldhouse and Davis channels)
Acres – 60,403
Prominent habitats – High salinity SAV, subtidal shell bottom, intertidal flats, intertidal shell bottom, soft bottom > 6 ft, inlet, tidal marsh
Ecological designations – Crab Spawning Sanctuary (CSS), Significant Natural Heritage Areas (SNHA),
Conservation Lands – Pea Island National Wildlife Refuge (NWR), Cape Hatteras National Seashore (NS), WRC managed island (C 05-06)
Fish data – yes
Prominent alterations present – minimal, trawling and dredging allowed in portions of area
Avg. total alteration score – 0.63
Avg. selection frequency – 424

SHA #123: Ocean, Platt Shoals (Map 10.5)

Description – nearshore Ocean adjacent to Oregon Inlet, Pea Island NWR
Acres – 36,137
Prominent habitats – marine soft bottom
Ecological designations –
Conservation Lands – Cape Hatteras National Seashore, Pea Island NWR
Fish data – yes
Prominent alterations present –
Avg. total alteration score – 0.96
Avg. selection frequency – 490

MAINLAND SHORELINE

SHA #150: Northwest Pamlico Shoreline (Map 10.5)

Description – western Pamlico Sound, north of Stumpy Point
Acres – 2,859
Prominent habitats – soft bottom 0-3 ft, > 6 ft, emergent and non-riparian wetlands
Ecological designations – SNHA
Conservation Lands – Alligator River NWR
Fish data – yes
Prominent alterations present –
Avg. total alteration score – 0.65

Avg. selection frequency – 89
Notes – recruitment area for blue crab larvae under certain weather conditions (Eggleston)

SHA #38: Parched Corn Bay (Map 10.6)

Description – western Pamlico Sound bay, just south of Stumpy Point
Acres – 4,971
Prominent habitats – soft bottom > 6 ft, soft bottom 0-3 ft, subtidal shell bottom
Ecological designations – SNHA
Conservation Lands – Alligator River NWR
Fish data – yes
Prominent alterations present – trawling, minor NPDES
Avg. total alteration score – 0.81
Avg. selection frequency – 377

SHA # 14:   Long Shoal River (Map 10.6)

Description – Long Shoal River, Pains Bay, Pamlico Sound
Acres – 15,163
Prominent habitats – emergent wetland, subtidal shell bottom, shallow – deep soft bottom
Ecological designations – PNA, SNA, SNHA
Conservation Lands – Alligator River NWR, Gull Rock Game Land, Dare County Air Force Range
Fish data – yes
Prominent alterations present – canals, wetlands lost to development, some bottom trawling, minor developed and agriculture land use
Avg. total alteration score – 0.45
Avg. selection frequency – 417

SHA # 21: Otter Creek (Map 10.6)

Description – bay and creek north of Engelhard, south of Long Shoal River, Juniper Swamp Point
Acres – 1,367
Prominent habitats – emergent wetlands, subtidal shell bottom, and shallow soft bottom 0-3 ft
Ecological designations – PNA, SNHA
Conservation Lands – Gull Rock Game Land
Fish data – no
Prominent alterations present – agriculture, minor NPDES
Avg. total alteration score – 0.36
Avg. selection frequency – 483

SHA #20: Far Creek (Map 10.6)

Description – embayment and creek near Engelhard, Gibbs Point, connected to Mattamuskeet draining canal
Acres – 5,344
Prominent habitats – emergent wetlands, soft bottom 0-3 ft, soft bottom > 6 ft, non-riparian wetlands, subtidal shell
Ecological designations – PNA, AFSA, SNHA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, canals and ditching, bottom disturbing gear, minor NPDES
Avg. total alteration score – 1.3
Avg. selection frequency – 406

SHA # 19: Middleton Creek (Map 10.7)

Description – embayment and creek near Middleton
Acres – 1,367
Prominent habitats – low elevation uplands, emergent wetlands, soft bottom 0-3 ft, non-riparian wetlands
Ecological designations – PNA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, canal and culverts, bottom disturbing gear, minor NPDES
Avg. total alteration score – 1.94
Avg. selection frequency – 490

SHA #49: Wysocking Bay (Map 10.7)

Description – large embayment southeast of Lake Mattamuskeet
Acres – 10,813
Prominent habitats – emergent wetlands, estuarine soft bottom, shallow to deep, low elevation uplands, subtidal shell bottom
Ecological designations – PNA, SPNA, AFSA, SNHA
Conservation Lands – Gull Rock Game Land
Fish data – yes
Prominent alterations present – culvert, bottom disturbing gear, minor NPDES
Avg. total alteration score – 0.71
Avg. selection frequency – 445

SHA #148: East Bluff Bay (Map 10.7)

Description – Embayment south of Wysocking Bay and near Outfall Canal
Acres – 249
Prominent habitats – emergent wetlands, soft bottom 0-3 ft.
Ecological designations – PNA, SNHA
Conservation Lands – Gull rock Game Land
Fish data – no
Prominent alterations present – minimal, bottom disturbing gear
Avg. total alteration score – 0.91
Avg. selection frequency – 500

SHA #27: Pamlico Sound Fish Area 3 (Map 10.7)

Description – soft bottom with good fish data
Acres – 870
Prominent habitats – soft bottom > 6 ft.
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score – 1.0
Avg. selection frequency – 52

PAMLICO RIVER MOUTH

SHA # 52: Swanquarter Bays (Map 10.8)

Description – Swanquarter, Rose, Juniper Bays, near Swanquarter, hydrologically connects with Lake Mattamuskeet via Rose Bay Canal
Acres – 60,900
Prominent habitats – estuarine soft bottom, emergent wetlands, soft bottom 0- 6 ft., non-riparian wetland, subtidal shell bottom, high salinity SAV
Ecological designations – PNA, SNA, ORW, SNHA
Conservation Lands – Gull Rock Gameland, Mattamuskeet NWR, Swanquarter NWR
Fish data – yes
Prominent alterations present – agriculture, ditching, bottom disturbing gear
Avg. total alteration score – 0.49
Avg. selection frequency – 410
Notes –good fish data in river

SHA #60: southeast Pungo River (Map 10.8)

Description – Slade and Fortescue creeks and Abel Bay
Acres – 17,276
Prominent habitats –Non-riparian wetlands, emergent wetlands, shallow to deep soft bottom, low elevation uplands, subtidal shell bottom, low salinity SAV, high salinity SAV
Ecological designations – PNA, SNA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, wetlands lost to development, ditched, bottom disturbing gear
Avg. total alteration score – 0.3
Avg. selection frequency – 495

SHA #69: Goose Creek Game Land 1 (Map 10.8)

Description – creeks and bays at south tip of Pamlico River, including Oyster Creek, Middle Prong, and some impoundments
Acres – 5,096
Prominent habitats – emergent wetlands, wetland edge, soft bottom 0-3 and 3-6 ft, high salinity SAV
Ecological designations – PNA, SNA, SNHA
Conservation Lands – Goose Creek Game Land
Fish data – yes
Prominent alterations present – drained, bottom disturbing gear
Avg. total alteration score – 0.9
Avg. selection frequency – 424

SHA #70: Goose Creek Game Land 2 (Map 10.8)

Description – Big Porpoise, Middle and Jones bays south of Pamlico River mouth; near Hobucken
Acres – 18,891
Prominent habitats – emergent wetlands, soft bottom 0-> 6 ft, subtidal shell bottom, high salinity SAV
Ecological designations – PNA, SNA, oyster sanctuary, SNHA
Conservation Lands – Goose Creek Game Land, Hobucken Marshes Preserve, military prohibited Brandt Island

Fish data – yes
Prominent alterations present – drained, military activities, bottom disturbing gear
Avg. total alteration score – 0.87
Avg. selection frequency – 425

SHA #65: Upper Middle Ground (Map 10.8)

Description – Subtidal oyster reefs with good fishing off Pamlico River
Acres – 4,474
Prominent habitats – soft bottom, subtidal shell bottom
Ecological designations – ORW
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score – 1.0
Avg. selection frequency – 46
Notes – oyster reefs and large red drum (per M. Marshall)

PAMLICO RIVER

SHA #130: southwest Pungo River (Map 10.9)

Description – creeks along lower and west of Pungo River and Pamlico River, includes North Creek,
Wades Point and Pamlico Beach
Acres – 8,451
Prominent habitats – non-riparian wetlands, soft bottom 0-3 ft., low elevation uplands, emergent wetland,
low salinity SAV.
Ecological designations – IPNA, PNA, SNA
Conservation Lands –
Fish data – yes
Prominent alterations present –
Avg. total alteration score –0.83
Avg. selection frequency – 490
Notes – healthy system

SHA #128: Jordan Creek (Map 10.9)

Description – Jordan Creek off Pungo River
Acres – 2,113
Prominent habitats – Non-riparian wetlands, soft bottom 0- >6, subtidal shell bottom
Ecological designations – IPNA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, culvert, wetlands lost to development and agriculture, bottom
disturbing gear, minor animal operations
Avg. total alteration score – 0.46
Avg. selection frequency – 471

SHA #40 : Pungo Creek (Map 10.9)

Description – mid- Pungo Creek, west of Hwy. 99

Acres – 1,491
Prominent habitats – soft bottom, subtidal shell bottom
Ecological designations –
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, bottom disturbing fishing gear, wetlands lost to development
Avg. total alteration score –0.96
Avg. selection frequency – 473

SHA #15: Pantego Creek (Map #10.9)

Description – Pantego Creek off Pungo River
Acres – 4,847
Prominent habitats – non-riparian wetlands, emergent wetlands
Ecological designations – SNHA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, minor NPDES, major animal operation, bottom disturbing gear
Avg. total alteration score – 0.67
Avg. selection frequency – 407

SHA #41: Tooley's Point (Map 10.9)

Description – bay and lower Dowry Creek by Tooley's Point near Bellhaven
Acres – 621
Prominent habitats – soft bottom 0-3 ft, low elevation upland
Ecological designations – PNA
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear, minor NPDES, multi-slip docks
Avg. total alteration score –0.8
Avg. selection frequency – 500

SHA #147: Haystack Point (Map 10.9)

Description – Flax Pond by Haystack Point, west of Upper Dowry Creek off Pungo River
Acres – 373
Prominent habitats – non-riparian wetland, soft bottom > 6 ft., soft bottom 0-3 ft., low elevation upland
Ecological designations – PNA
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear, shoreline stabilization, minor NPDES
Avg. total alteration score –0.56
Avg. selection frequency – 500

SHA # 17: Upper Pungo River (Map 10.9)

Description – Upper Pungo to Hwy 264 and Hwy 45
Acres – 2,610
Prominent habitats – emergent wetlands, soft bottom 0-3, soft bottom > 6, low salinity SAV
Ecological designations – SNA, SNHA
Conservation Lands – Pungo River Game Land

Fish data – yes
Prominent alterations present – agriculture, bottom disturbing gear
Avg. total alteration score – 0.46
Avg. selection frequency – 43

SHA #51: South and Goose Creeks (Map 10.10)

Description – South, Bond, Goose, Eastham and Campbell creeks, south side of Pamlico River, southeast of PCS, near Aurora
Acres – 21,626
Prominent habitats – wetland edge, emergent wetland, non-riparian wetland, low salinity SAV
Ecological designations – IPNA, PNA, SNA, SNHA
Conservation Lands – Goose Creek Game Land
Fish data – yes
Prominent alterations present – drained, minor NPDES, bottom disturbing gear
Avg. total alteration score – 0.97
Avg. selection frequency – 457

SHA #61: Durham Creek (Map 10.10)

Description – Durham Creek, south side of Pamlico River, west of PCS
Acres – 4,101
Prominent habitats – non-riparian wetlands, forested wetlands, soft bottom 3-6 ft
Ecological designations – PNA, IPNA, AFSA, SNHA
Conservation Lands –
Fish data – yes
Prominent alterations present – major NPDES, bottom disturbing gear
Avg. total alteration score – 1.30
Avg. selection frequency – 500

SHA # 54: Mixon Creek (Map 10.10)

Description – Mixon Creek west of Gum Point near Bayview
Acres – 870
Prominent habitats – non-riparian wetlands, soft bottom 0-3
Ecological designations – IPNA
Conservation Lands –
Fish data – yes
Prominent alterations present – major NPDES
Avg. total alteration score – 1.88
Avg. selection frequency – 500

SHA #44: Bath Creek (Map 10.11)

Description – Bath Creek
Acres – 3,977
Prominent habitats – forested wetlands, soft bottom >6 ft, soft bottom 0-3 ft
Ecological designations – IPNA
Conservation Lands – Bath State Historic Site
Fish data – yes
Prominent alterations present – agriculture, residential development along shoreline, wetlands lost to development, bottom disturbing fishing gear
Avg. total alteration score – 0.87

Avg. selection frequency – 490
SHA #42: Goose Creek State Park (Map 10.11)

Description – Duck, Little Goose, and Broad creeks along Pamlico River shoreline, west of Bath
Acres – 4,723
Prominent habitats – forested wetlands, soft bottom 0-3 ft, low elevation upland, low salinity SAV
Ecological designations – IPNA, SNA, AFSA, SNHA
Conservation Lands – Goose Creek State Park
Fish data – yes
Prominent alterations present – relatively minor, some agriculture, bottom disturbing fishing gear
Avg. total alteration score – 0.32
Avg. selection frequency – 482

SHA #47: Blount's Bay (Map 10.11)

Description – Blount's Bay and Blount's Creek off Pamlico River, just south of Chocowinity.
Acres – 13,796
Prominent habitats – soft bottom > 6ft, forested wetland, low salinity SAV, soft bottom 0-3ft
Ecological designations – SNA, AFSA, SNHA
Conservation Lands – Nevil's Creek Land Trust and Preserve
Fish data – yes
Prominent alterations present – agriculture and residential development, obstruction, bottom disturbing gear
Avg. total alteration score – 0.53
Avg. selection frequency – 485

SHA # 43: Upper Pamlico River, Washington (Map 10.11)

Description – Upper Pamlico River north of Chocowinity Bay, up to Tranters Creek
Acres – 2,486
Prominent habitats – forested wetlands
Ecological designations – IPNA, SNA, AFSA, SNHA
Conservation Lands –
Fish data – no
Prominent alterations present – developed north shore, minor NPDES, bridges
Avg. total alteration score – 0.89
Avg. selection frequency – 414
Notes – good striper fishing, especially around bridge pilings

SHA # 2: Lower Fishing Creek (Map 10.12)

Description – Fishing Creek – upper Tar River, just above Tarboro
Acres – 621
Prominent habitats – forested wetland, riverine soft bottom
Ecological designations – AFSA, SNHA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, culvert (road bisects), wetlands lost to agriculture
Avg. total alteration score – 0.63
Avg. selection frequency – 38
Notes – Check on why – fairly close to Tarboro or major highways, low selection freq

SHA #4: Tar River, Rocky Mount (Map 10.12)

Description – Tar River just below Rocky Mills Dam
Acres – 10,191
Prominent habitats – forested wetland, riverine rocky bottom, wetland edge
Ecological designations – IPNA, AFSA, SNHA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture and developed (Rocky Mount), dam, impoundment, major NPDES, hog lagoon,
Avg. total alteration score – 1.17
Avg. selection frequency – 485

SHA # 1: Upper Fishing Creek   (Map 10.12)

Description – Fishing Creek – upper Tar River, above Tarboro, on Halifax/Edgecombe county line
Acres – 870
Prominent habitats – forested wetland, riverine stream, mid elevation
Ecological designations – AFSA, SNHA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture (forestry), minor NPDES
Avg. total alteration score – 1.52
Avg. selection frequency – 82
Notes – American shad use for spawning (B.Wynne, WRC, personal communication)

PAMLICO-NEUSE BAYS

SHA #78: Bay River (Map 10.13)

Description – Bay River and adjacent bays and creeks including Bear, Gale, Vandemere creeks and Bonner Bay; Near Vandemere
Acres – 20383
Prominent habitats – soft bottom 0-3 and >6 ft, emergent wetland, non-riparian wetland, subtidal shell bottom, high salinity SAV
Ecological designations – PNA, SNA, SNHA
Conservation Lands – Hobucken Marshes Preserve, Lampe-Woodard tract land trust
Fish data – yes
Prominent alterations present – agriculture, drained, bottom disturbing gear
Avg. total alteration score – 0.83
Avg. selection frequency – 471

SHA #81: Chapel Creek (Map 10.13)

Description – Chapel Creek in upper Bay River
Acres – 1,243
Prominent habitats – soft bottom, emergent wetland
Ecological designations – PNA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, drained, obstructions, animal operations
Avg. total alteration score – 1.31

Avg. selection frequency – 100

SHA #144: Moore Bay (Map 10.13)

Description – creek feeding into Moore Bay on upper south side of Bay River
Acres – 497
Prominent habitats – non-riparian wetlands, soft bottom 0-3 and >6 ft
Ecological designations – PNA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, drained, bottom disturbing gear
Avg. total alteration score – 0.87
Avg. selection frequency – 500

SHA #149: Upper Bay River (Map 10.13)

Description – single hex in upper Bay River – PNA
Acres – 124
Prominent habitats – non-riparian wetlands, soft bottom 0-3 and >6 ft
Ecological designations – PNA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, drained, bottom disturbing gear
Avg. total alteration score – 1.51
Avg. selection frequency – 500

SHA #82: Mason Bay (Map 10.13)

Description – creek feeding into Mason Bay on upper south side of Bay River
Acres – 621
Prominent habitats – low elevation upland, non-riparian wetland, emergent wetland
Ecological designations – PNA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, drained, major animal operation
Avg. total alteration score – 0.93
Avg. selection frequency – 471

NEUSE RIVER

SHA # 137: Neuse Mouth 1 (Map 10.14)

Description – subtidal oyster reefs in mouth of Neuse River
Acres – 6,339
Prominent habitats – subtidal shell bottom, soft bottom > 6 ft
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score – 1.02
Avg. selection frequency – 330

SHA # 86: Neuse Mouth 2 (Map 10.14)

Description – just outside Neuse mouth
Acres – 11,683
Prominent habitats – good fish data, shell bottom, soft bottom >6 ft
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score –1.01
Avg. selection frequency – 281

SHA #91: Neuse Oyster Rock 3 (Map 10.14)

Description – subtidal oyster reef, center of Neuse, west of Rattan Bay
Acres – 1,725
Prominent habitats – subtidal oyster reefs, soft bottom > 6ft
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present –
Avg. total alteration score – 1.01
Avg. selection frequency – 313
Notes – good drum fishing and oysters

SHA # 96: West Bay (Map 10.14)

Description – mouth of West Bay
Acres – 7,333
Prominent habitats – shallow to deep soft bottom, high salinity SAV
Ecological designations – SNHA
Conservation Lands – Cedar Island NWR, Piney Island, military prohibited area (BT-11)
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score – 0.69
Avg. selection frequency – 78

SHA #97: Turnagain Bay area (Map 10.15)

Description – Turnagain Bay, upper South River, west side of Long Bay
Acres – 20,756
Prominent habitats – emergent wetland, soft bottom >6ft, non-riparian wetland, headwater wetland, some high salinity SAV and subtidal shell bottom
Ecological designations – PNA, oyster sanctuary, SNHA
Conservation Lands – Carteret County Game Land, Turnagain Bay Preserve, Piney Island Marine Corps land, military prohibited area (BT-11)
Fish data – yes
Prominent alterations present – agriculture, bottom disturbing gear
Avg. total alteration score –0.31
Avg. selection frequency – 408

SHA # 107: West Thorofare Bay (Map 10.15)

Description – West Thorofare, upper Long Bay, Cedar Island
Acres – 5,220
Prominent habitats – Emergent wetlands, non-riparian wetlands, high salinity SAV
Ecological designations – PNA, SNHA
Conservation Lands – Cedar Island NWR
Fish data – no
Prominent alterations present – agriculture, drained
Avg. total alteration score – 0.08
Avg. selection frequency – 358
Notes – connects to Thorofare Bay, good shrimping area

SHA #106: Sandy Point (Map 10.15)

Description – Neuse shoal between Adams and South River
Acres – 746
Prominent habitats – forested wetland, emergent wetland
Ecological designations – PNA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, wetlands lost to agriculture and development
Avg. total alteration score – 0.21
Avg. selection frequency – 362

SHA #109: Back Creek (Map 10.15)

Description – Back Creek, tributary of Adams Creek, headwaters in Open Grounds Farm
Acres – 3,853
Prominent habitats – non-riparian wetland, low elevation upland, emergent wetland
Ecological designations – PNA
Conservation Lands –
Fish data – no
Prominent alterations present – agriculture, bottom disturbing gear, drained
Avg. total alteration score – 0.73
Avg. selection frequency – 492

SHA # 110: Adams Creek (Map 10.15)

Description – Adams Creek mouth and side tributary near Merimon
Acres – 2,983
Prominent habitats – soft bottom 0-3 ft, emergent wetlands, low elevation upland
Ecological designations – PNA, SNA
Conservation Lands –
Fish data –
Prominent alterations present – agriculture, bottom disturbing gear, wetlands lost to development
Avg. total alteration score – 0.84
Avg. selection frequency – 491

SHA #136: Broad Creek (Map 10.16)

Description – Broad Creek, north mouth of Neuse River
Acres – 8,079
Prominent habitats – soft bottom 0-3 ft, emergent wetland, high salinity SAV
Ecological designations – PNA, SNA
Conservation Lands –   NGO owned tract
Fish data – yes
Prominent alterations present – drained, obstruction, bottom disturbing gear, multi-slip docking, minor NPDES
Avg. total alteration score – 0.77
Avg. selection frequency – 452

SHA #100: Green Creek (Map 10.16)

Description – Green, Whittaker, Pierce, and Orchard creeks at Oriental
Acres – 5,966
Prominent habitats – soft bottom 0-3 ft, emergent wetlands
Ecological designations – PNA, SNA, AFSA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, multi-slip docking, drained
Avg. total alteration score – 0.95
Avg. selection frequency – 499

SHA # 105: Neuse Oyster Rock 1 (Map 10.17)

Description – subtidal oyster reef, center of Neuse opposite Adams Creek
Acres – 1,616
Prominent habitats – subtidal shell bottom, soft bottom > 6ft
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score –1.01
Avg. selection frequency – 386

SHA #102: Neuse Oyster Rock 2 (Map 10.17)

Description – subtidal oyster reef, center of Neuse near South Creek

Acres – 621
Prominent habitats – subtidal shell bottom, soft bottom > 6ft
Ecological designations –
Conservation Lands –
Fish data – yes
Prominent alterations present – bottom disturbing gear
Avg. total alteration score – 1.01
Avg. selection frequency – 431

SHA #104: Dawson Creek (Map 10.17)

Description – Dawson Creek, between Minnesott Beach and Oriental
Acres – 1,864
Prominent habitats – soft bottom > 6 ft, emergent wetlands, soft bottom 0-3 ft

Ecological designations – PNA, SNA, AFSA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, bottom disturbing gear
Avg. total alteration score – 0.64
Avg. selection frequency – 293

SHA # 98: Beard's Creek (Map 10.17)

Description – Beards Creek near Arapahoe
Acres – 2,610
Prominent habitats – emergent wetlands, low salinity SAV
Ecological designations – PNA, AFSA
Conservation Lands –
Fish data – yes
Prominent alterations present – agriculture, development along shore, multi-slip docking facilities, minor NPDES, bottom disturbing gear
Avg. total alteration score – 0.50
Avg. selection frequency – 500

SHA #113: Clubfoot Creek (Map 10.17)

Description – Clubfoot Creek, connected to Harlowe Creek (tributary of Newport River) via canal
Acres – 5,841
Prominent habitats – non-riparian wetland, soft bottom 0- ft, forested wetland, some low salinity SAV
Ecological designations – PNA, SNA
Conservation Lands – Croatan National Forest
Fish data – no
Prominent alterations present – agriculture and development, obstruction, wetlands lost to agriculture
Avg. total alteration score – 0.59
Avg. selection frequency – 488

SHA #112: Hancock Creek (Map 10.17)

Description – Hancock Creek, south side of Neuse, near Cherry Point
Acres – 4,971
Prominent habitats – soft bottom 0-3 ft, forested wetland, low elevation upland, low salinity SAV
Ecological designations – IPNA, SNHA
Conservation Lands – Croatan National Forest
Fish data – no
Prominent alterations present – development, obstructions, wetlands lost to development
Avg. total alteration score – 0.66
Avg. selection frequency – 500
Notes – metal contamination but not as bad as Slocum; lot of recreational fishing for speckled trout, red drum, striped bass

SHA # 134: Goose Creek (Map 10.18)

Description – Goose and Upper Broad creeks just east of Fairfield Harbour
Acres – 7,954
Prominent habitats – forested wetland, non-riparian wetland, low salinity SAV
Ecological designations – SNA, AFSA, SNHA
Conservation Lands – Neuse River Game Land

Fish data – yes
Prominent alterations present – agriculture, development, wetlands lost to agriculture and development, bottom disturbing gear
Avg. total alteration score – 0.23
Avg. selection frequency – 454

SHA # 99: Neuse shoreline, James City (Map 10.18)

Description – 1,491
Acres – 1,491
Prominent habitats – soft bottom >6 ft, low salinity SAV
Ecological designations –
Conservation Lands –
Fish data – no
Prominent alterations present – development, bottom disturbing gear
Avg. total alteration score – 1.3
Avg. selection frequency – 500
Notes – high bluff shoreline

SHA #93: Trent River (Map 10.18)

Description – Trent River
Acres – 7,581
Prominent habitats – forested wetland, riverine soft bottom, low salinity SAV
Ecological designations – SNHA
Conservation Lands – Brice's Creek Land Trust, Croatan National Forest, Sawmill Wetland Mitigation Site
Fish data – no
Prominent alterations present – development, multi-slip docking, minor NPDES, bottom disturbing gear, wetlands lost to development
Avg. total alteration score – 1.12
Avg. selection frequency – 468

SHA # 83: Upper Neuse 1   (Map 10.19)

Description – Upper Neuse just upstream of New Bern, adjacent to Weyerhauser and including Hog Island, Hwy. 43 crosses it
Acres – 4,474
Prominent habitats – forested wetland, riverine soft bottom
Ecological designations – SNA, SNHA
Conservation Lands – Bellair Plantation Preserve and Land Trust, Neuse River Game Land
Fish data – no
Prominent alterations present – development, major NPDES, wetlands lost to development
Avg. total alteration score – 0.65
Avg. selection frequency – 400
Notes- known as good fish area, WRC, pers. communication

SHA #71: Riverine Upper Neuse 2 (Map 10.19)

Description – Pitch Kettle, Village, Core, Kidney creeks, further upstream than #83
Acres – 7,582
Prominent habitats – forested wetland, riverine soft bottom
Ecological designations – IPNA, AFSA, SNHA

Conservation Lands –

Fish data –yes, WRC

Prominent alterations present – agriculture, major animal operation, wetlands lost to development

Avg. total alteration score – 0.37

Avg. selection frequency – 20

Notes –Pitch Kettle used by hickory shad, Core, Village and Kidney creeks have relatively more and consistent use by juvenile blueback herring than anywhere else in Neuse or Tar. (B. Wynne, WRC, personal communication)

SHA # 140: Riverine Upper Neuse 3 (Map 10.20)

Description – Rocky bottom area of upper Neuse, upstream of former Quaker Neck dam, Goldsboro

Acres – 22,371

Prominent habitats – forested wetland, riverine soft bottom, riverine hard bottom

Ecological designations – IPNA, AFSA, SNHA

Conservation Lands – Poplar Creek Bluffs Land Trust, Montgomery Laurel Bluffs Preserve, Land Trust

Fish data –no

Prominent alterations present – agriculture, development, NPDES, animal operations

Avg. total alteration score – 0.73

Avg. selection frequency – 477

Notes- good fish area, WRC, pers. comm.
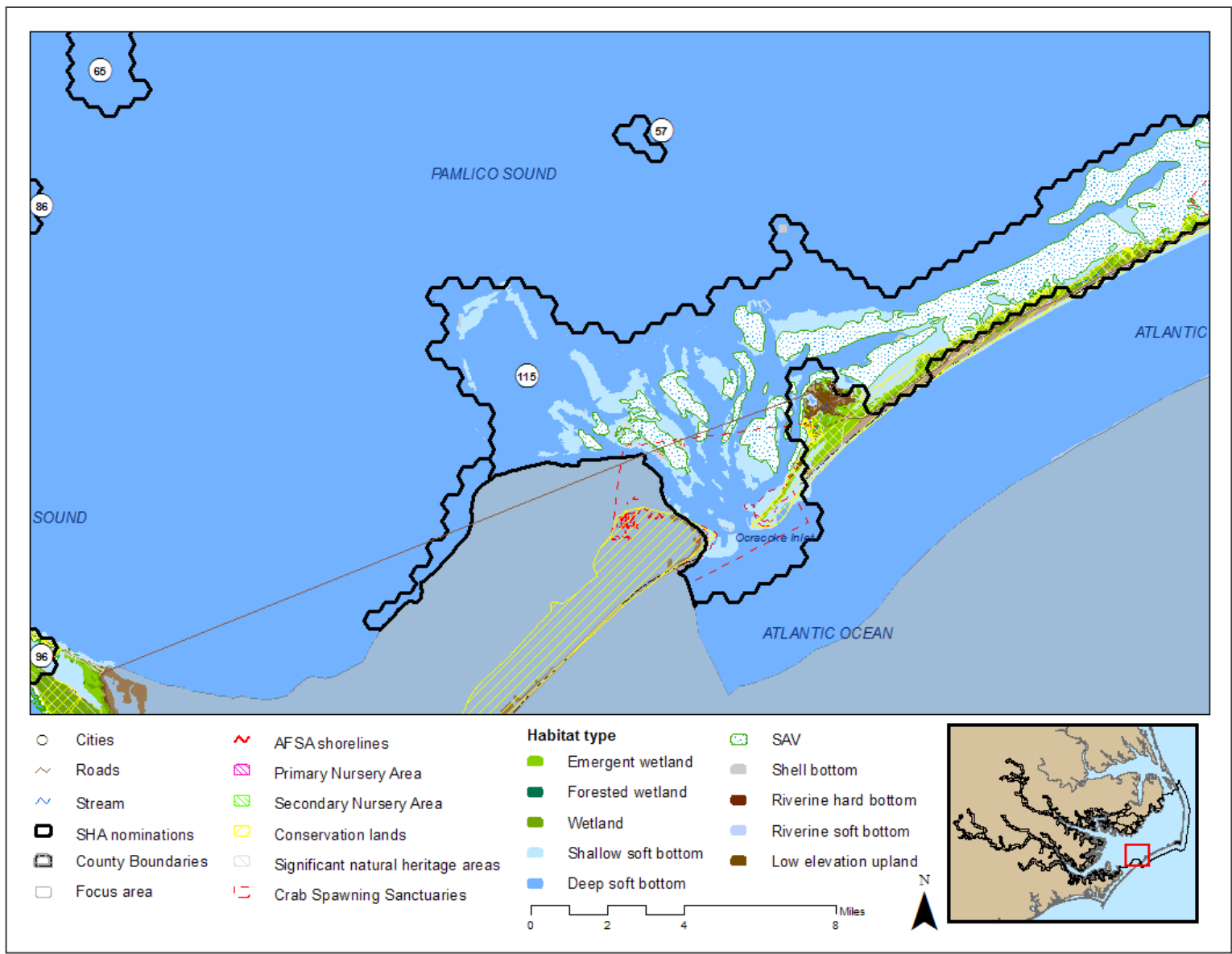
Map 10.1. Region 2 Strategic Habitat Areas (SHAs): Ocracoke Inlet and Pamlico Sound (SHAs 115 & 57).
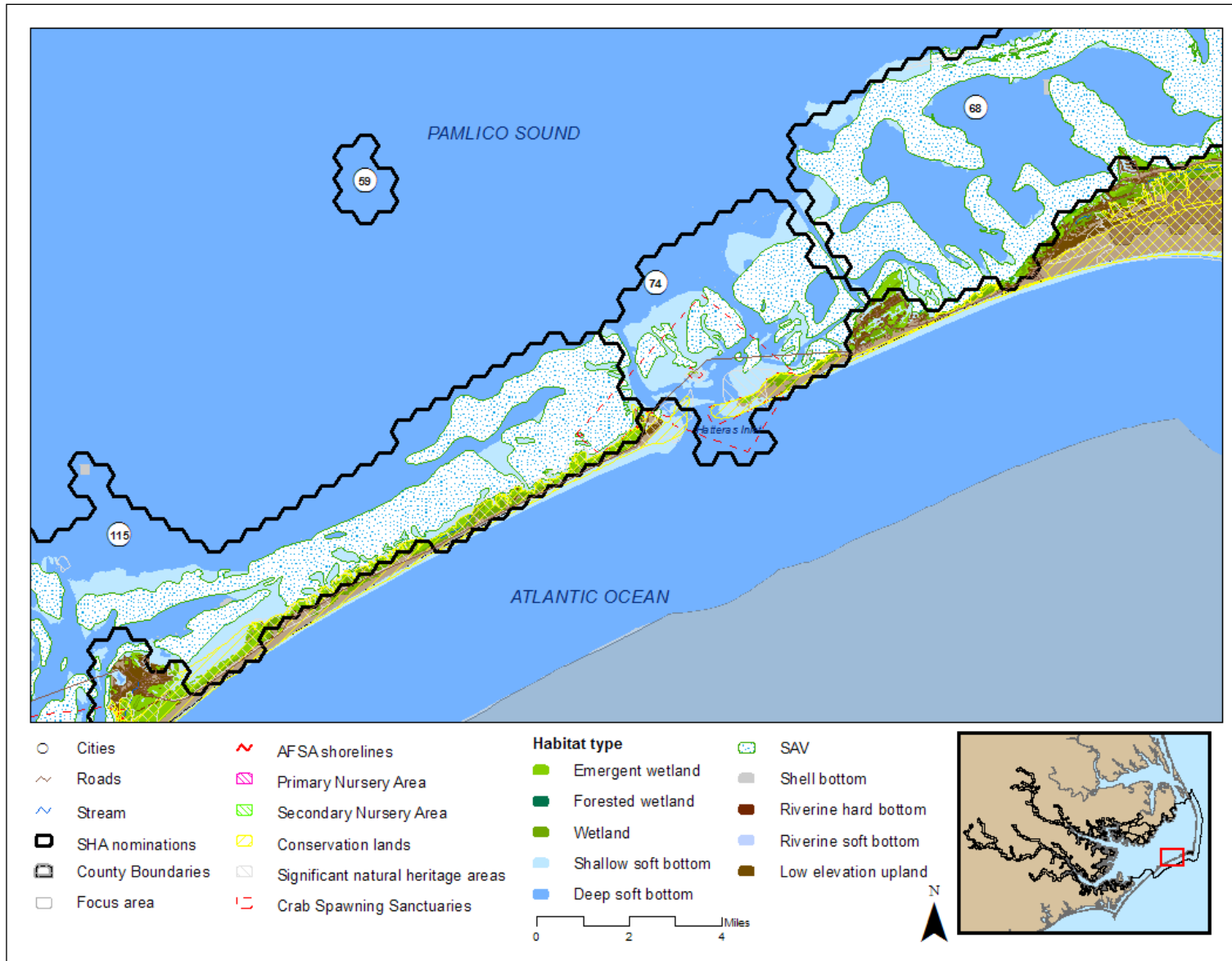
Map 10.2. Region 2 Strategic Habitat Areas (SHAs): Hatteras Inlet and Pamlico Sound (SHAs 74 & 59).
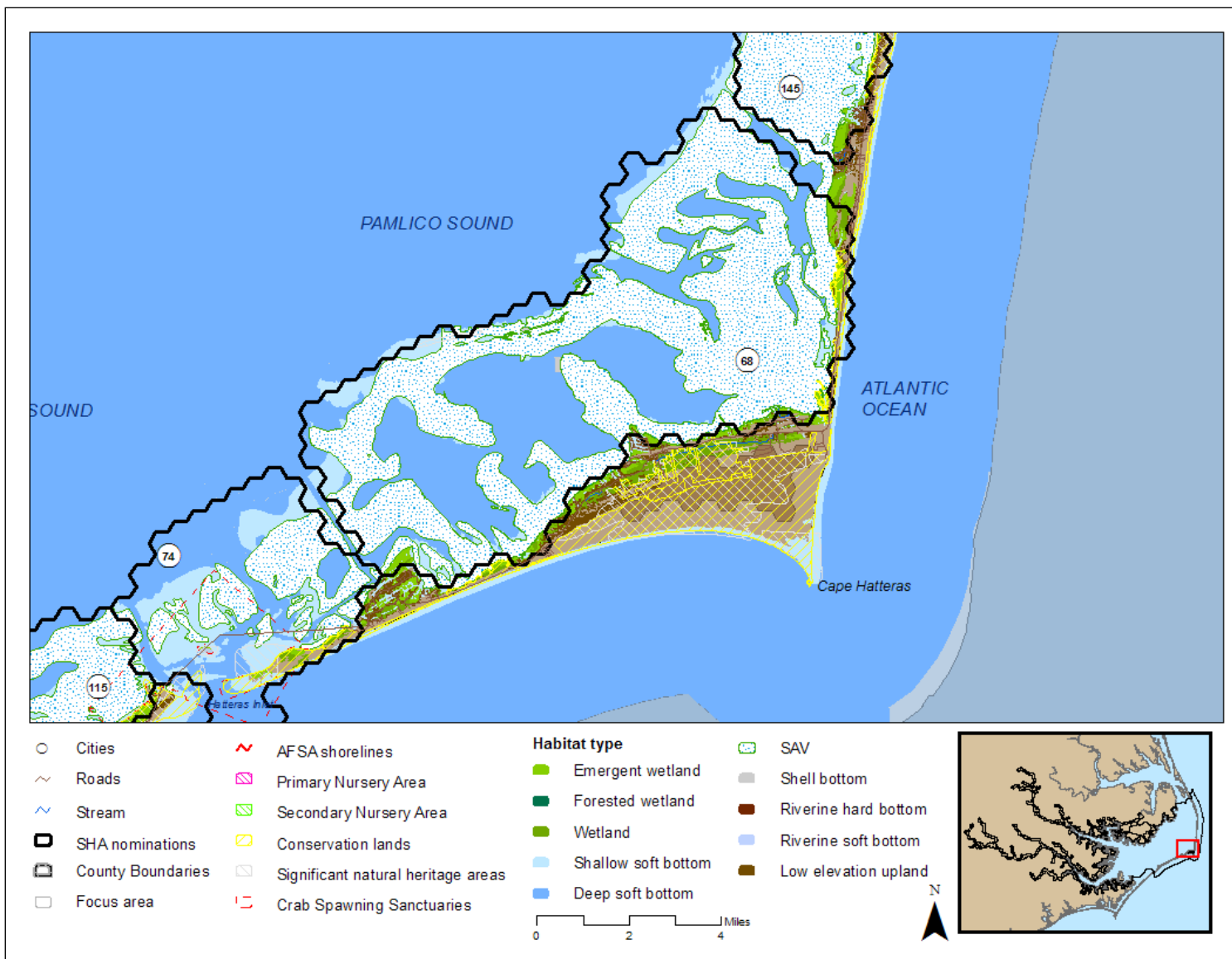
Map 10.3. Region 2 Strategic Habitat Areas (SHAs): Eastern Pamlico Sound, Hatteras Inlet (SHAs 68 & 74).
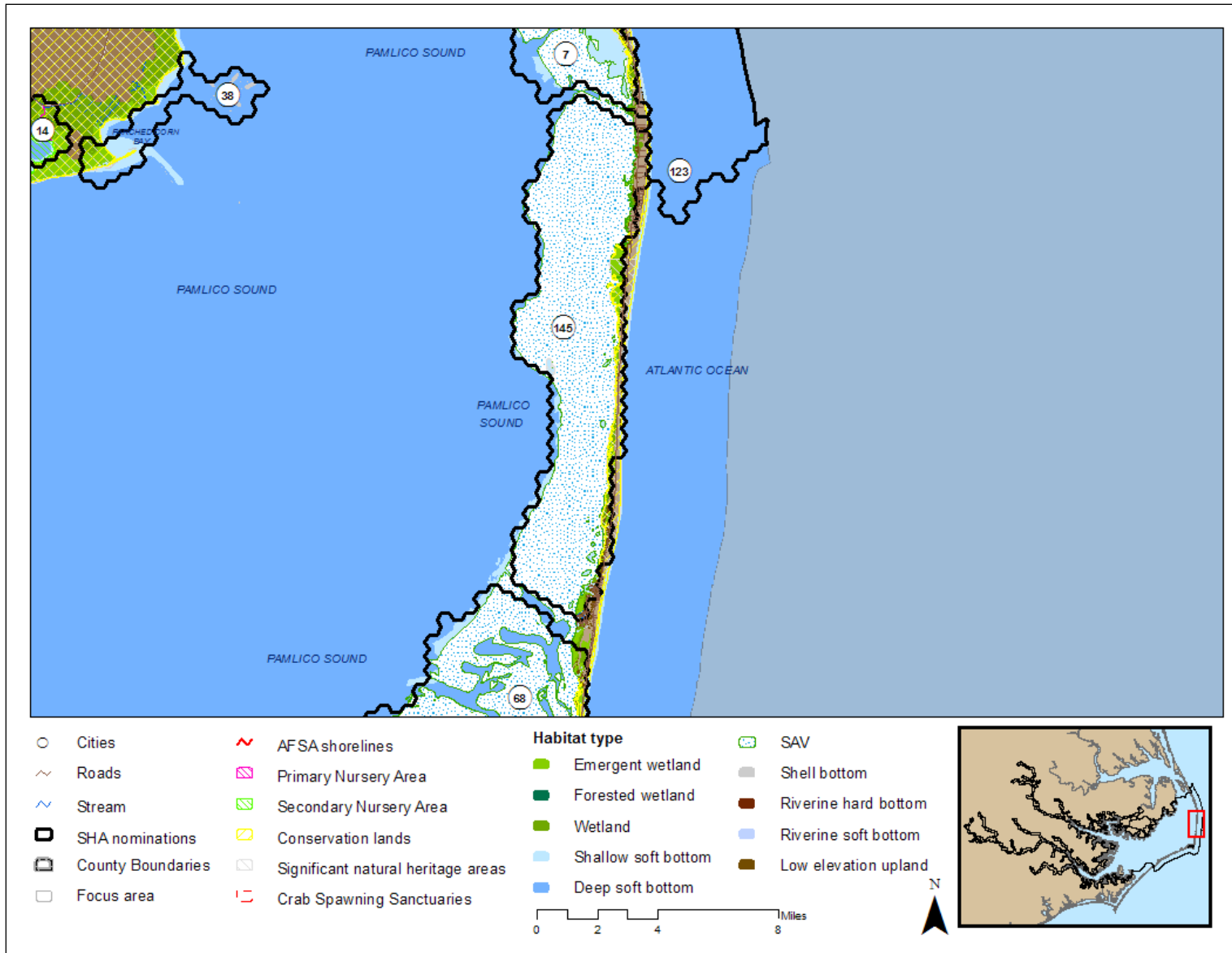
Map 10.4. Region 2 Strategic Habitat Areas (SHAs): Eastern Pamlico Sound (SHA 145).
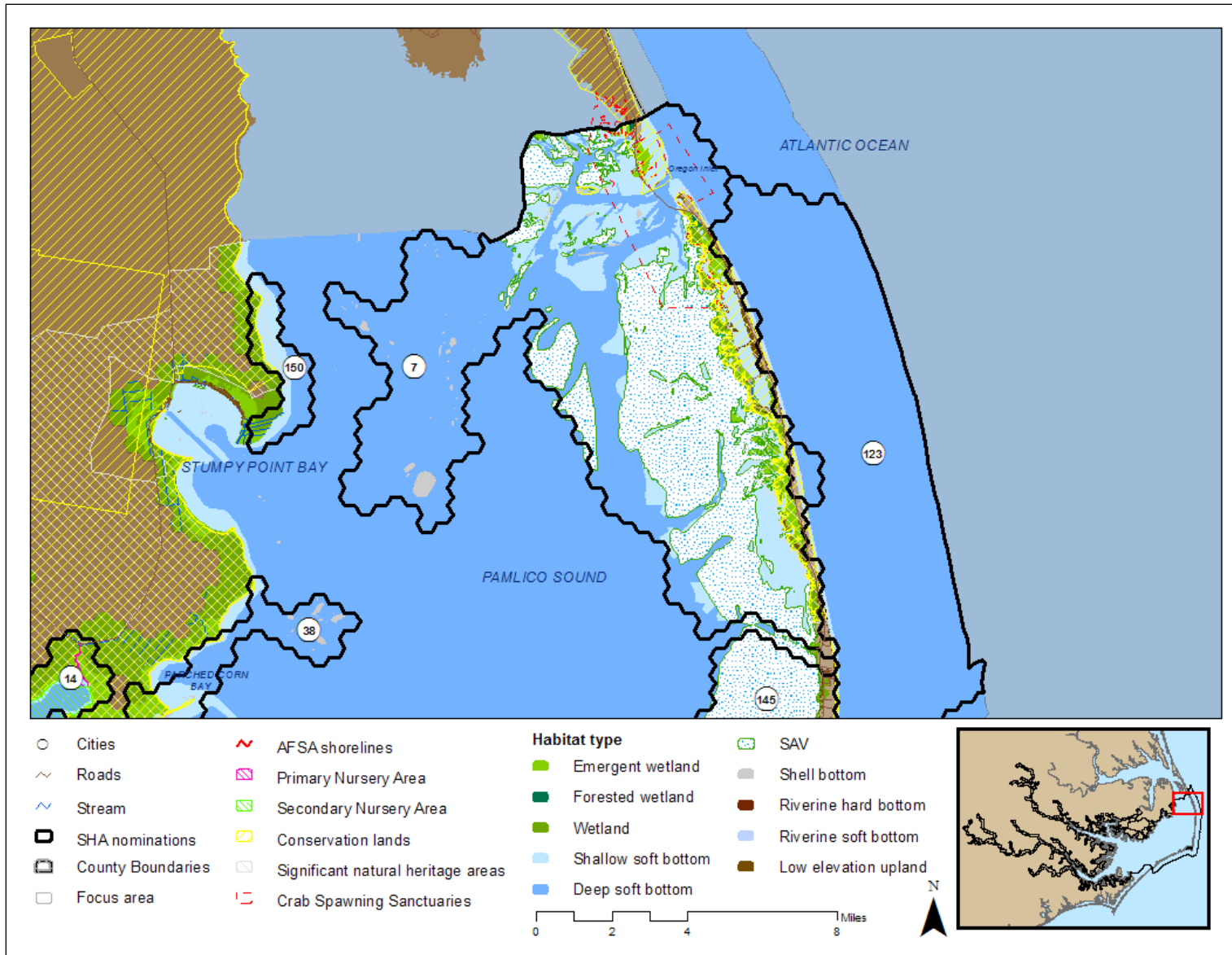
Map 10.5. Region 2 Strategic Habitat Areas (SHAs): Eastern Pamlico Sound (SHAs 123, 7, & 150).
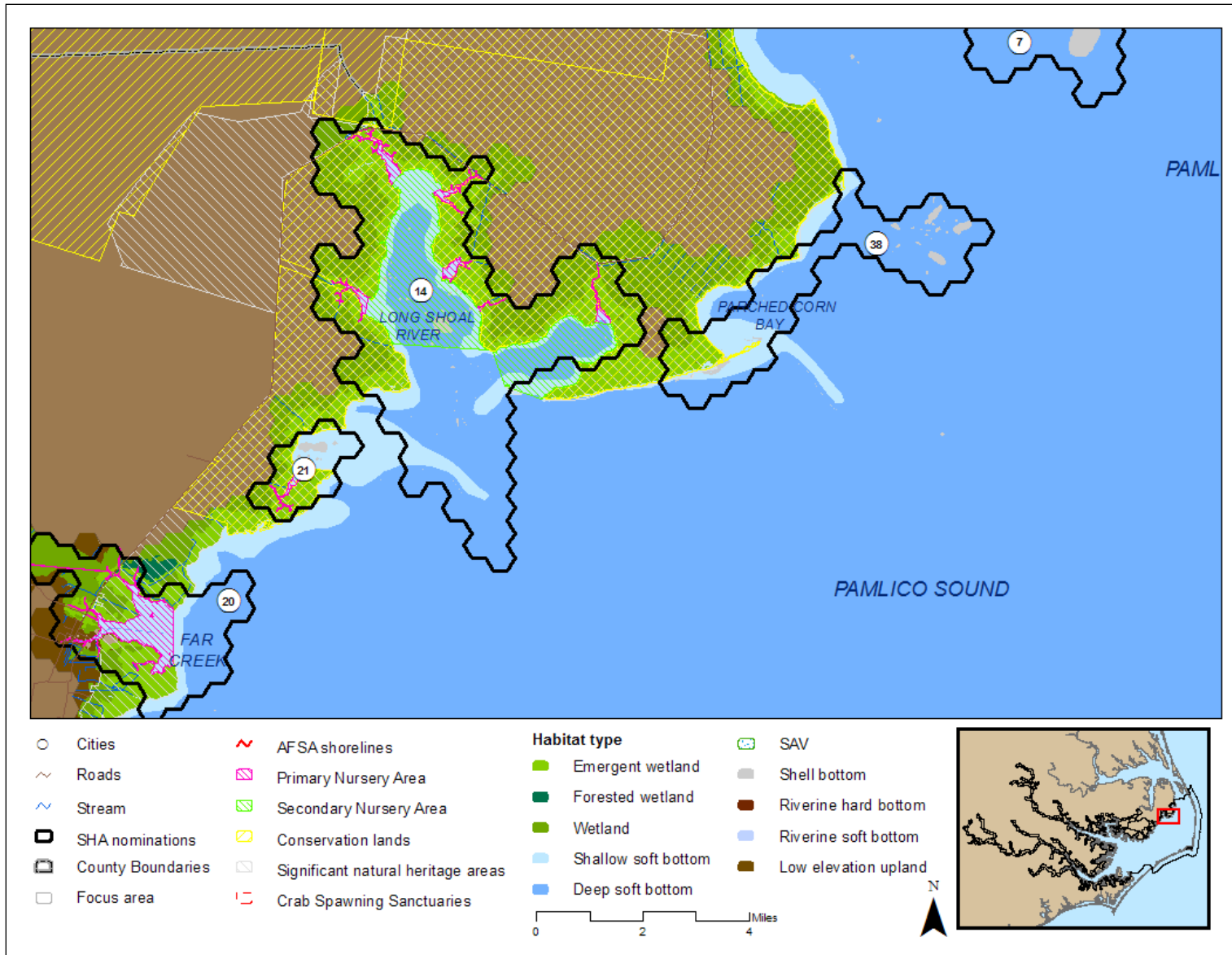
Map 10.6. Region 2 Strategic Habitat Areas (SHAs): Northwestern Pamlico Sound, Long Shoal River area (SHAs 38, 14, 21, & 20).
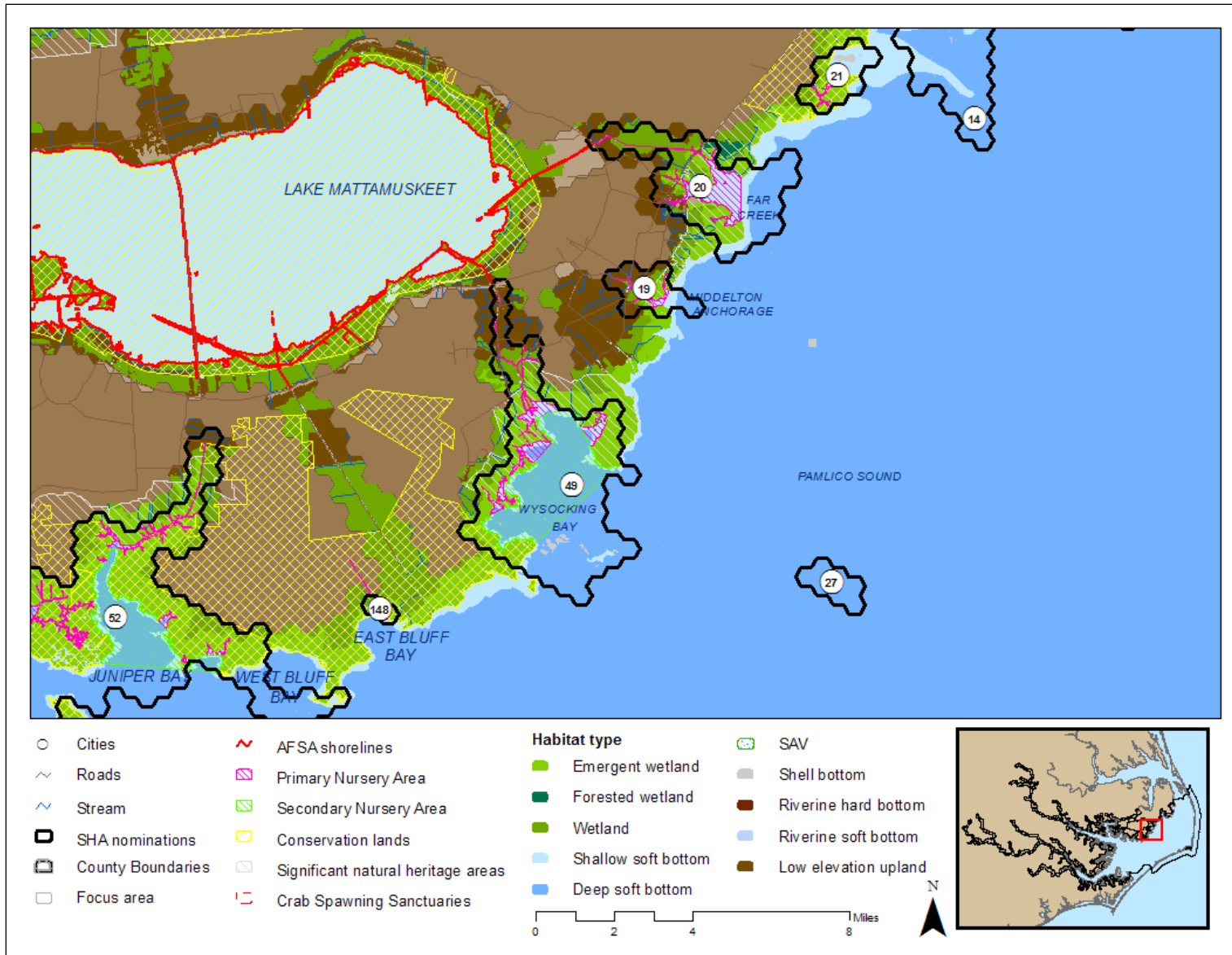
Map 10.7. Region 2 Strategic Habitat Areas (SHAs): Western Pamlico Sound bays, Wysocking Bay area (SHAs 19, 49, 148, & 27).
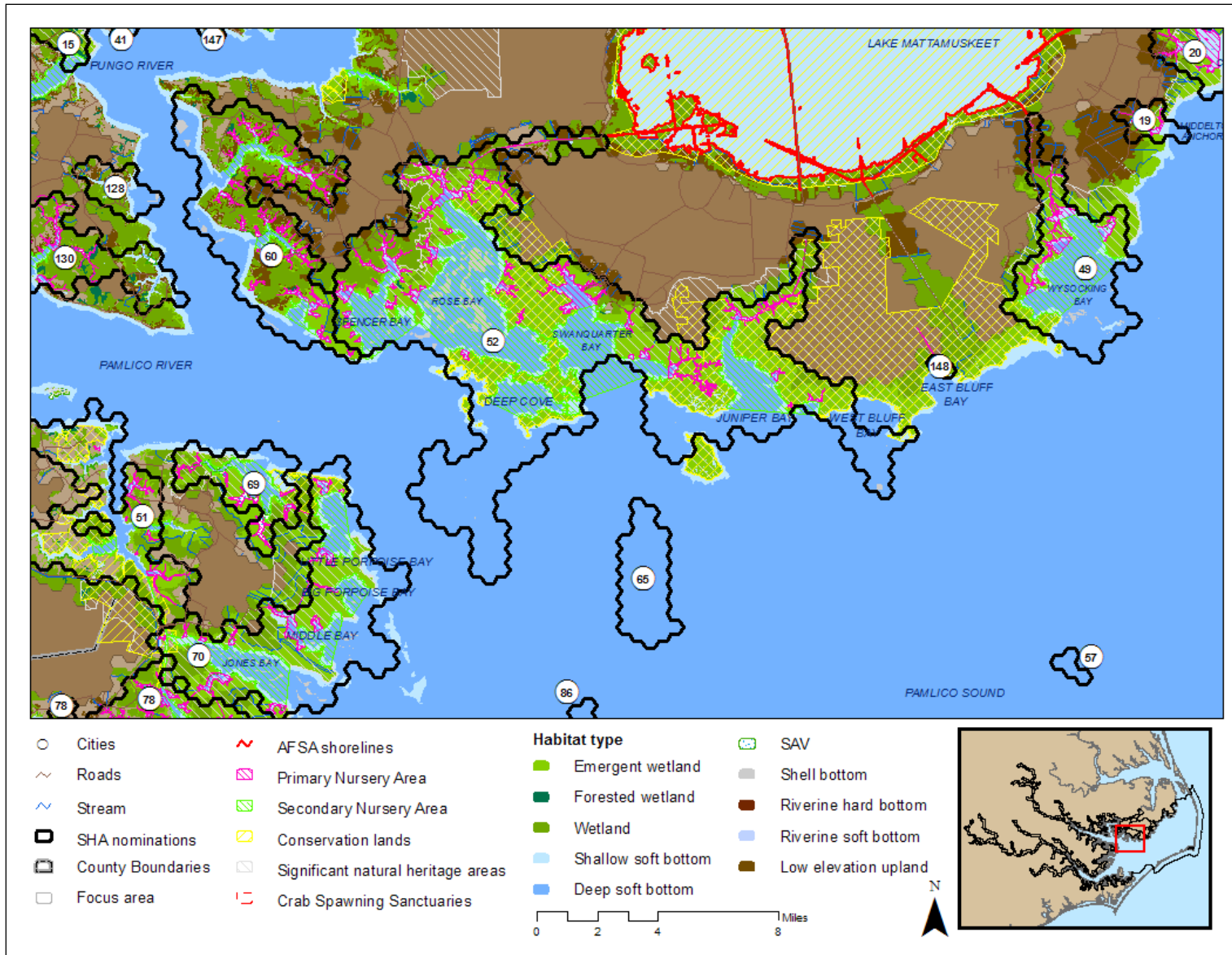
Map 10.8. Region 2 Strategic Habitat Areas (SHAs): Pamlico River mouth and bays, including Juniper, Swanquarter, Rose, Porpoise, and Jones bays (SHAs 52, 60, 69, 70, 65, & 57).
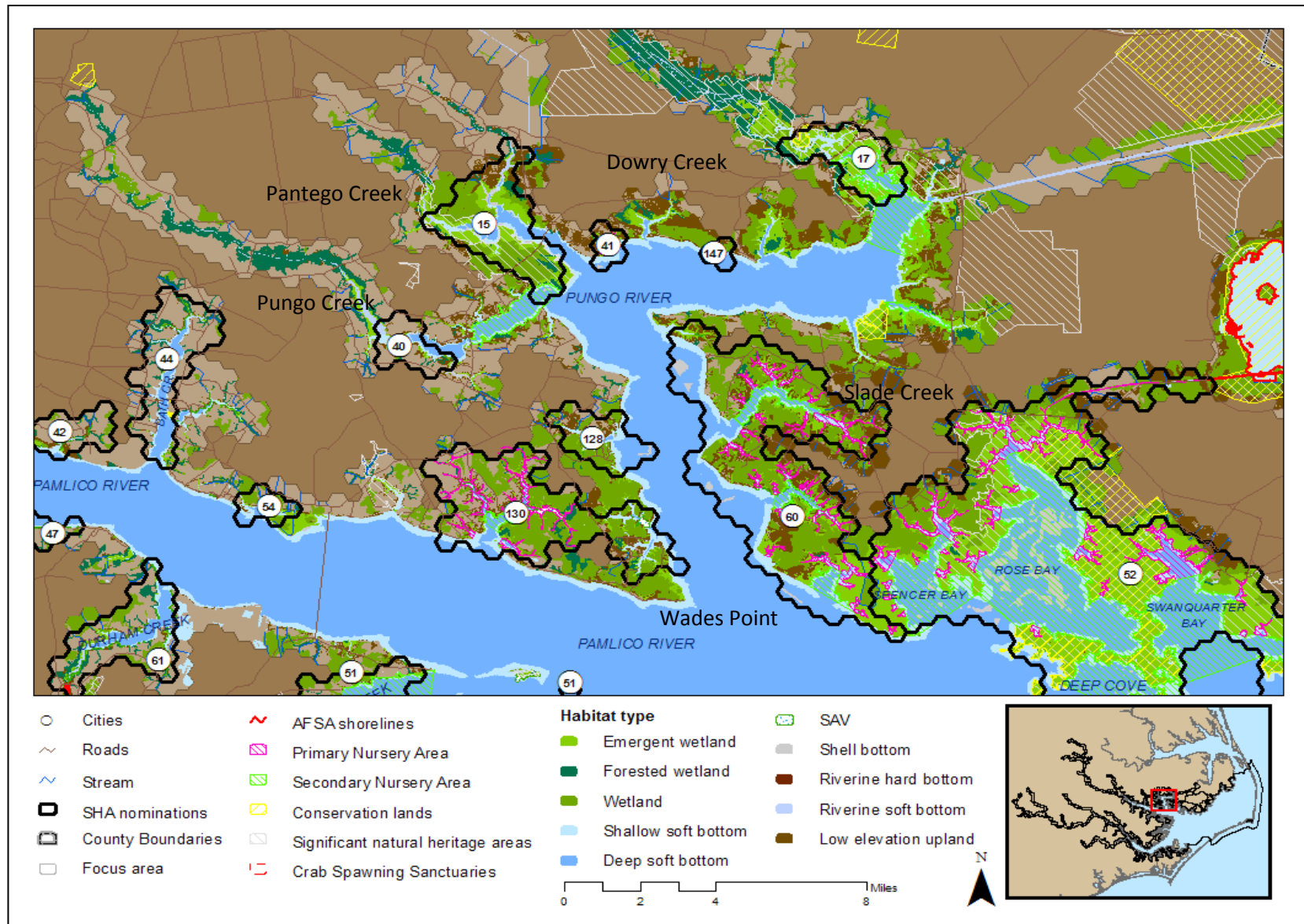
Map 10.9. Region 2 Strategic Habitat Areas (SHAs): Pungo and lower Pamlico rivers, including Pungo, Pantego, Downy, and Slade creeks (SHAs 60, 130, 128, 40, 15, 41, 147, 17, & 54).
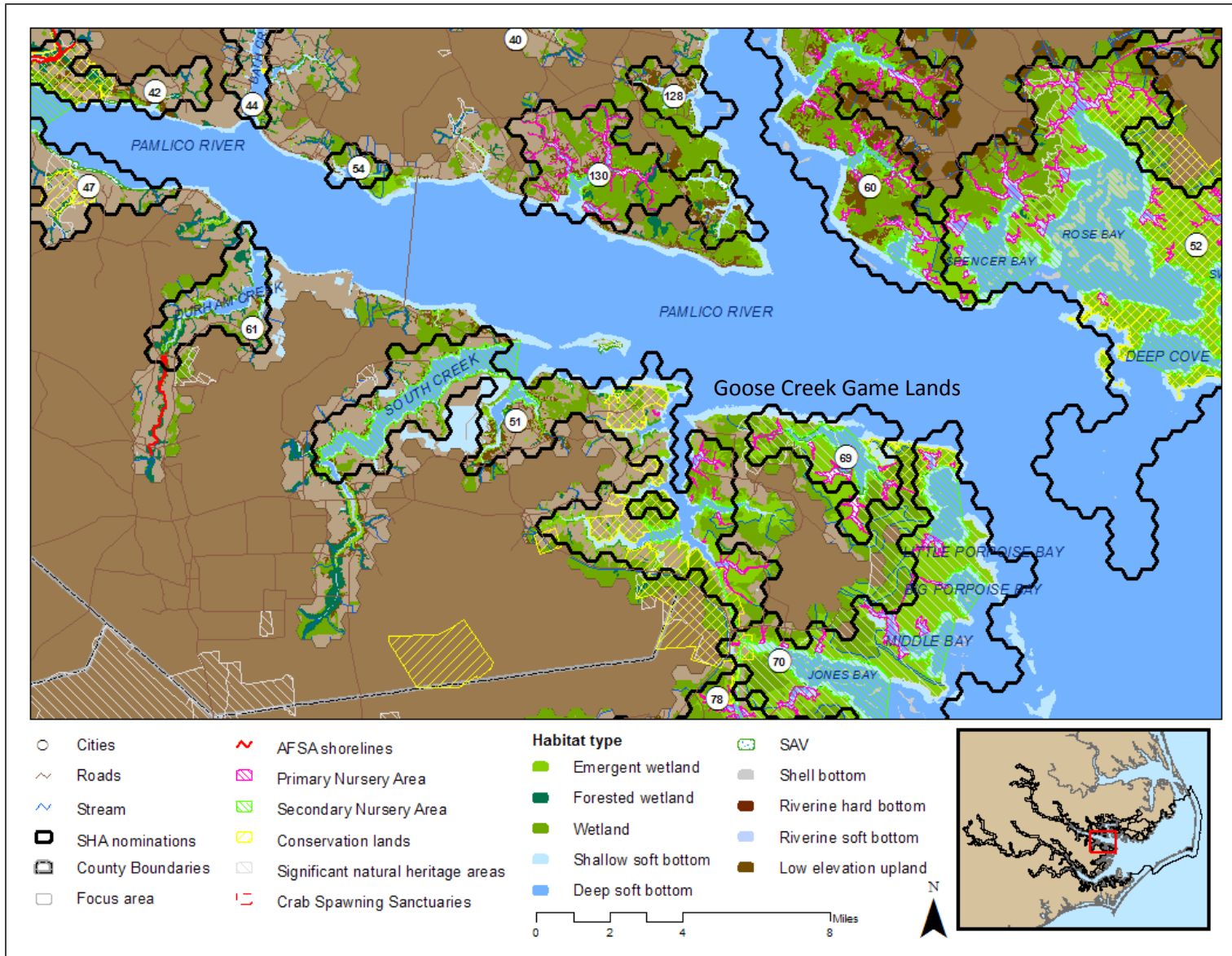
Map 10.10. Region 2 Strategic Habitat Areas (SHAs): Pamlico River, South Creek area (SHAs 51, 61, 44, & 54).
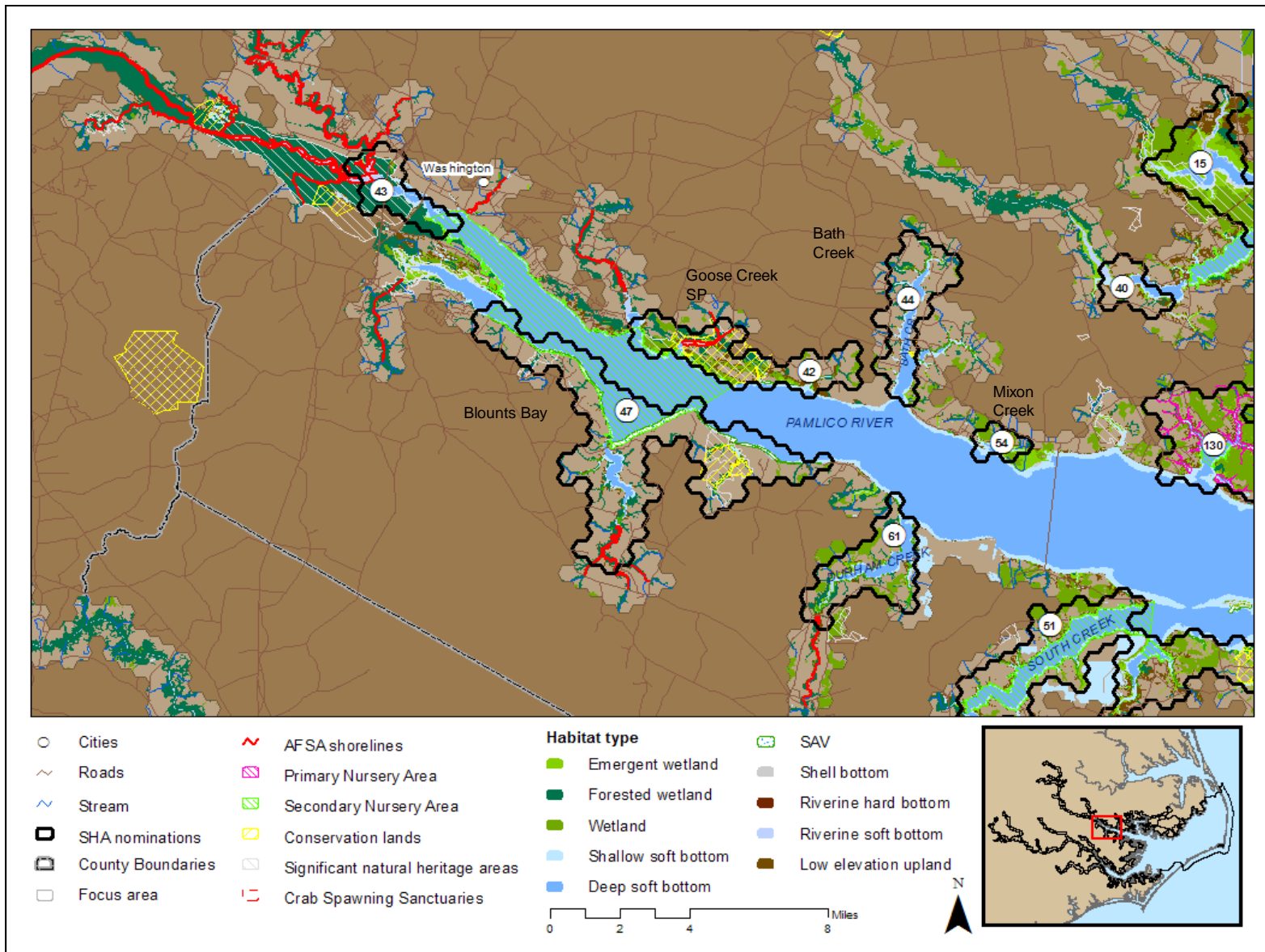
Map 10.11. Region 2 Strategic Habitat Areas (SHAs): Pamlico River near Washington, including Blount's Bay, Bath Creek, and Goose Creek State Park (SHAs 44, 42, 47, & 43).
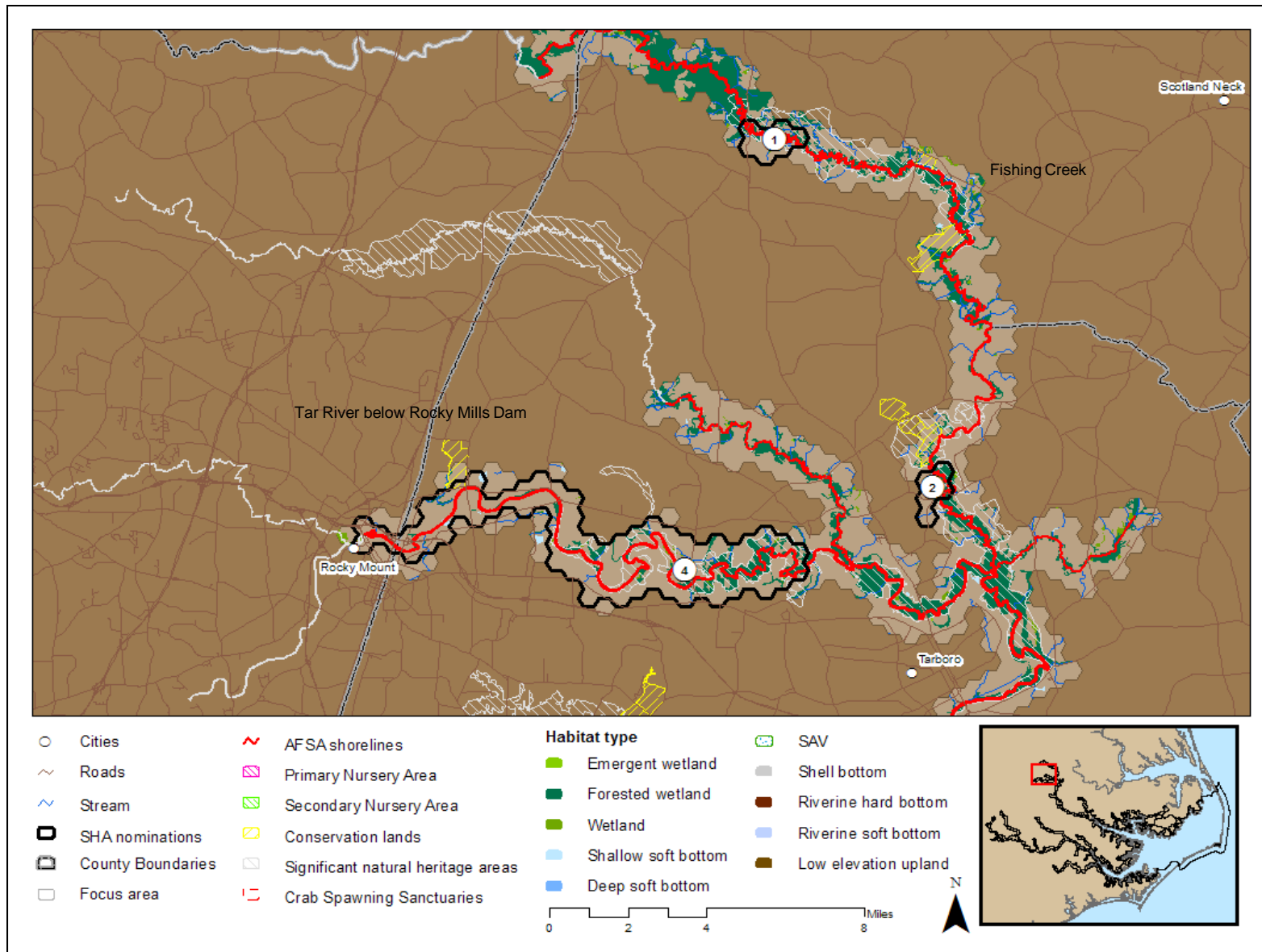
Map 10.12. Region 2 Strategic Habitat Areas (SHAs): Upper Pamlico River near Rocky Mount (SHAs 2, 4, & 1).
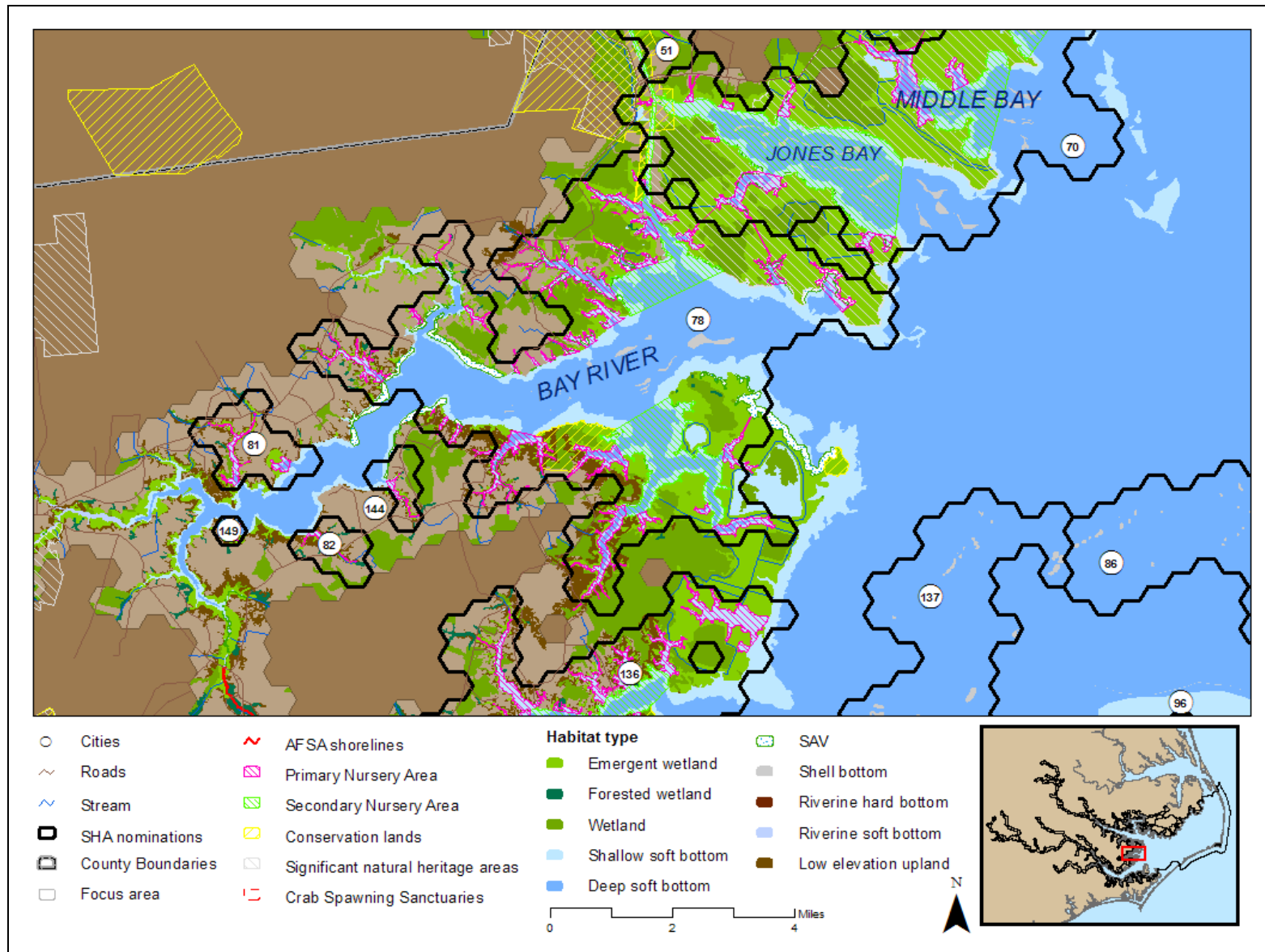
Map 10.13. Region 2 Strategic Habitat Areas (SHAs): Neuse River bays (SHAs 78, 81, 144, 149, & 82).
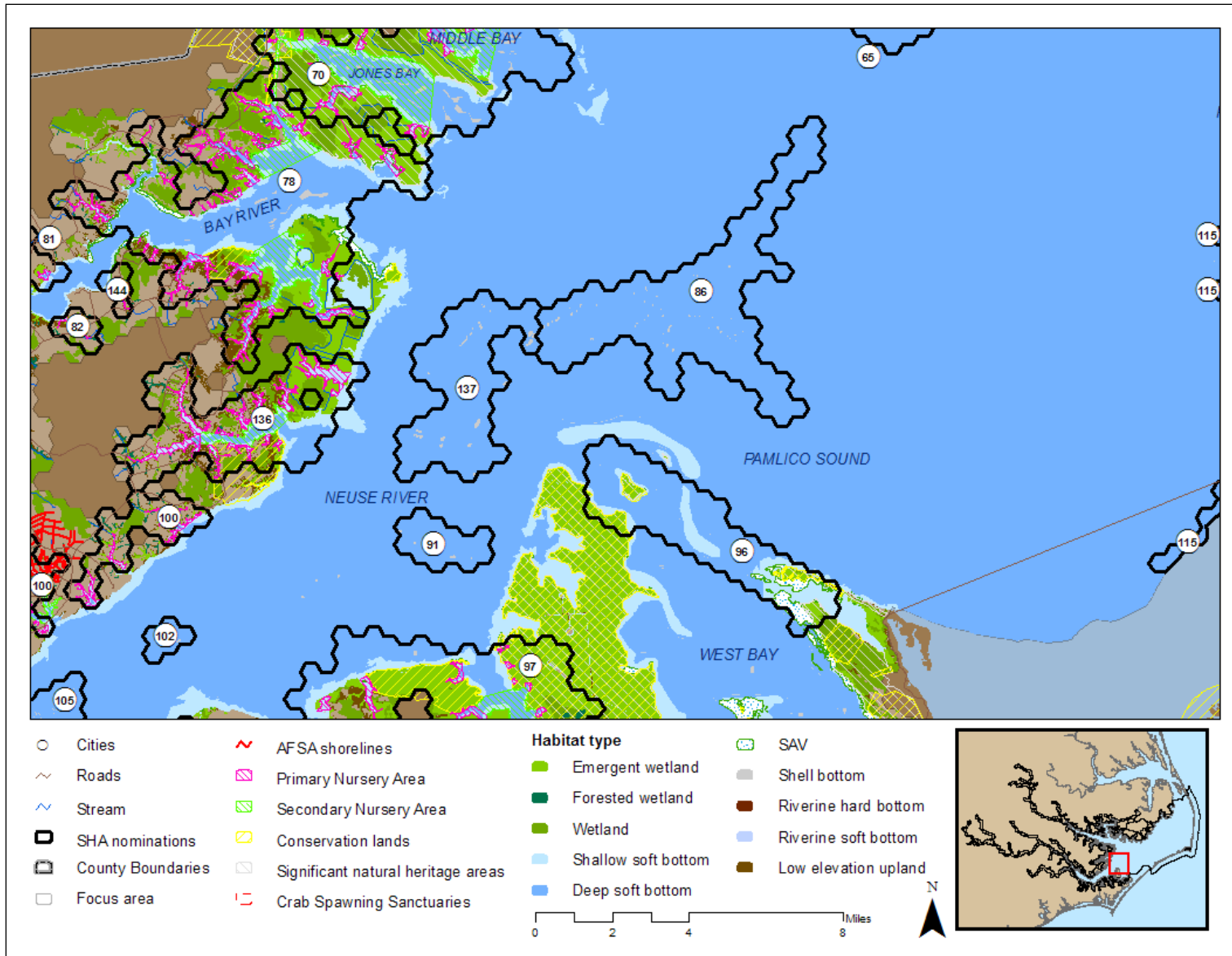
Map 10.14. Region 2 Strategic Habitat Areas (SHAs): Neuse River mouth (SHAs 137, 86, 91, & 96).
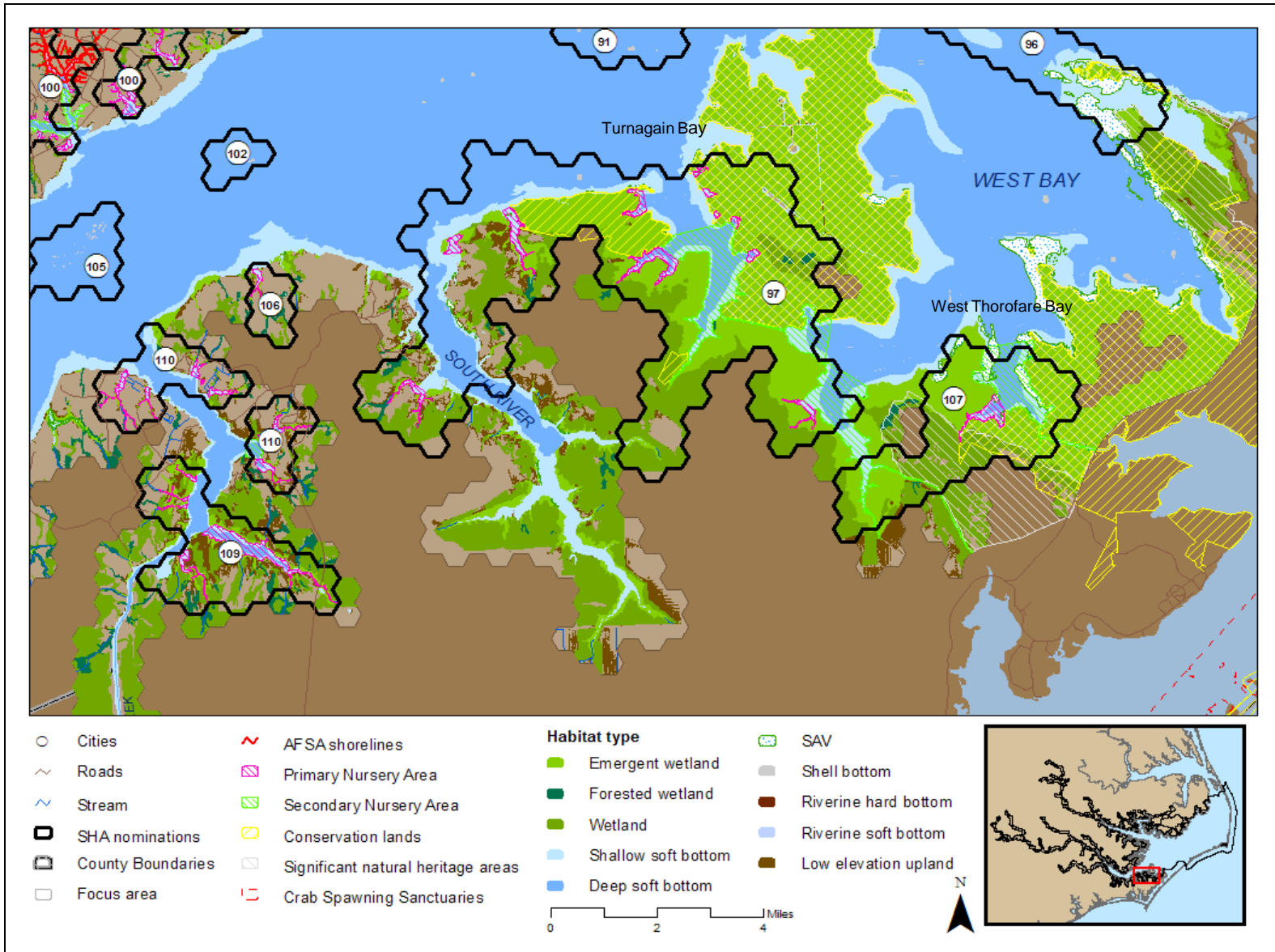
Map 10.15. Region 2 Strategic Habitat Areas (SHAs): Lower Neuse River, South River, West Bay (SHAs 97, 107, 106, 109, & 110).
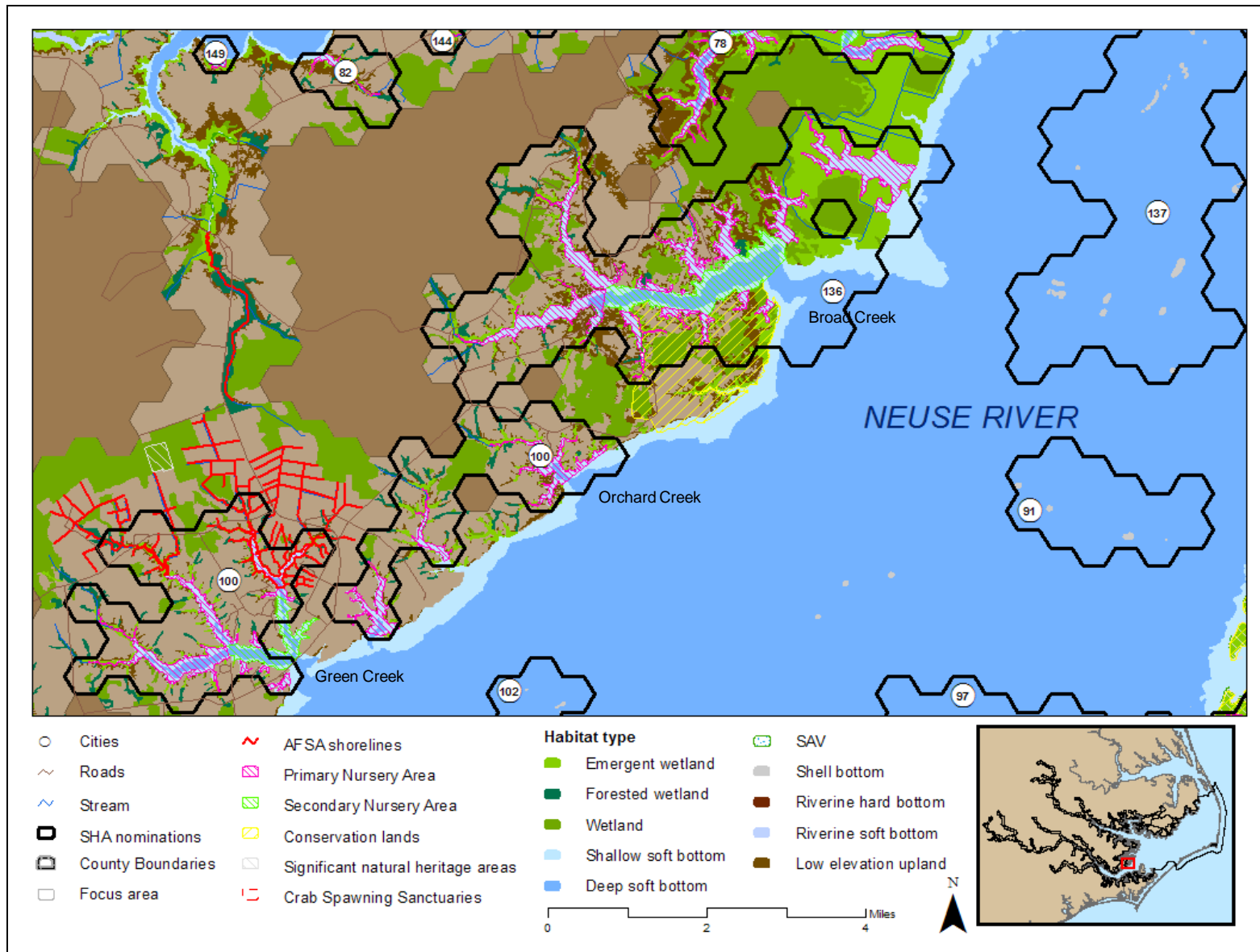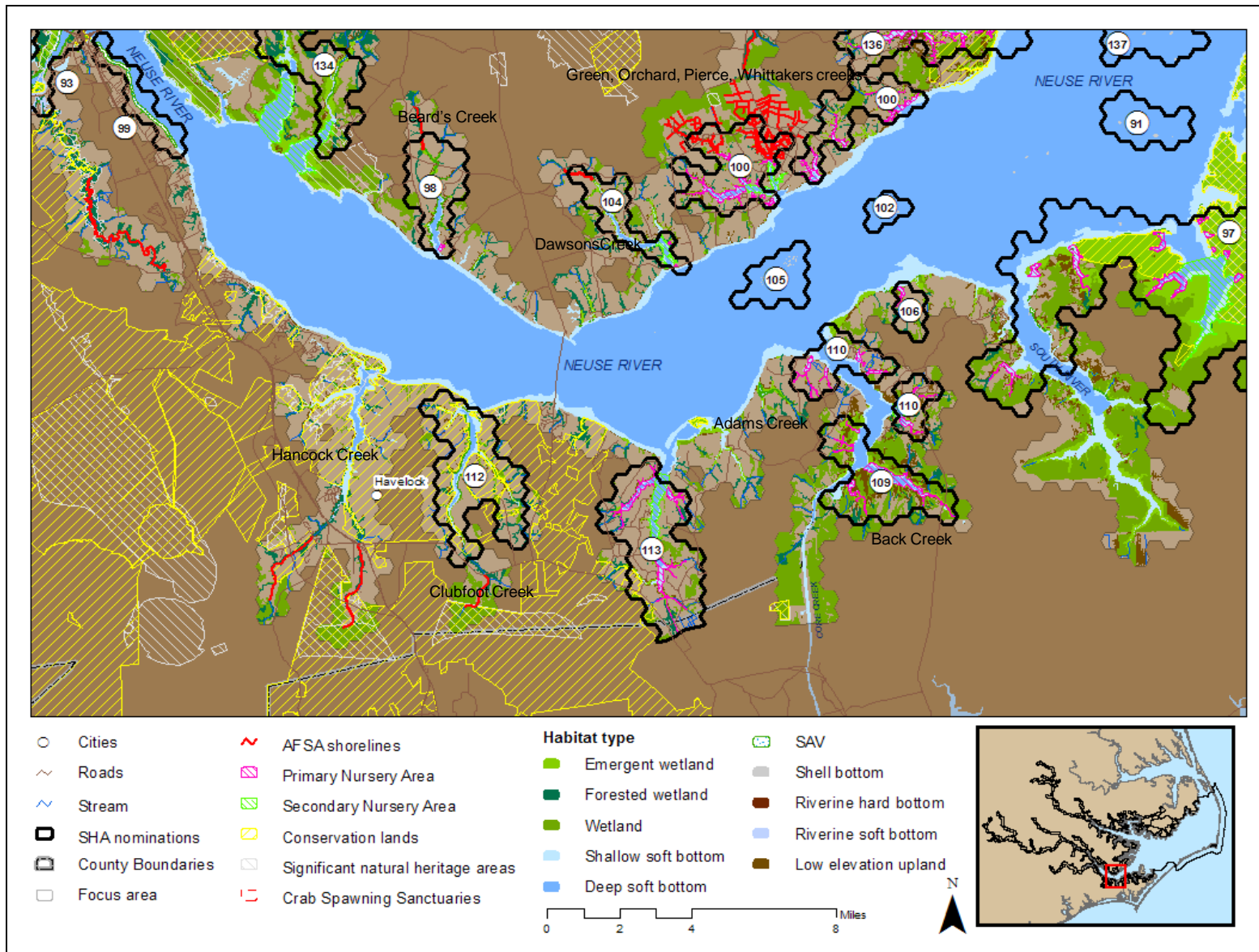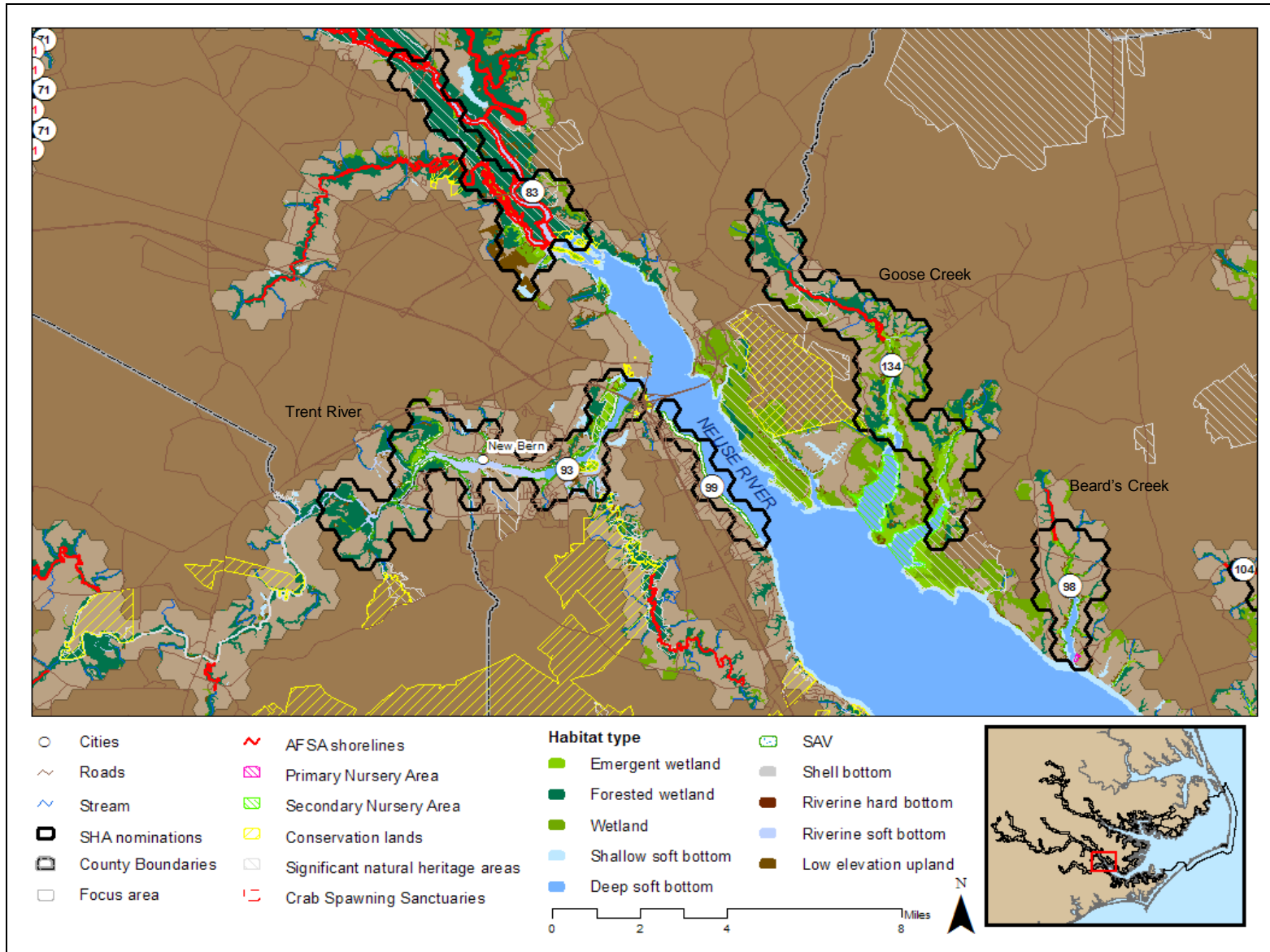
Map 10.16. Region 2 Strategic Habitat Areas (SHAs): Lower Neuse River and Broad, Orchard, and Green creeks (SHAs 136 & 100).
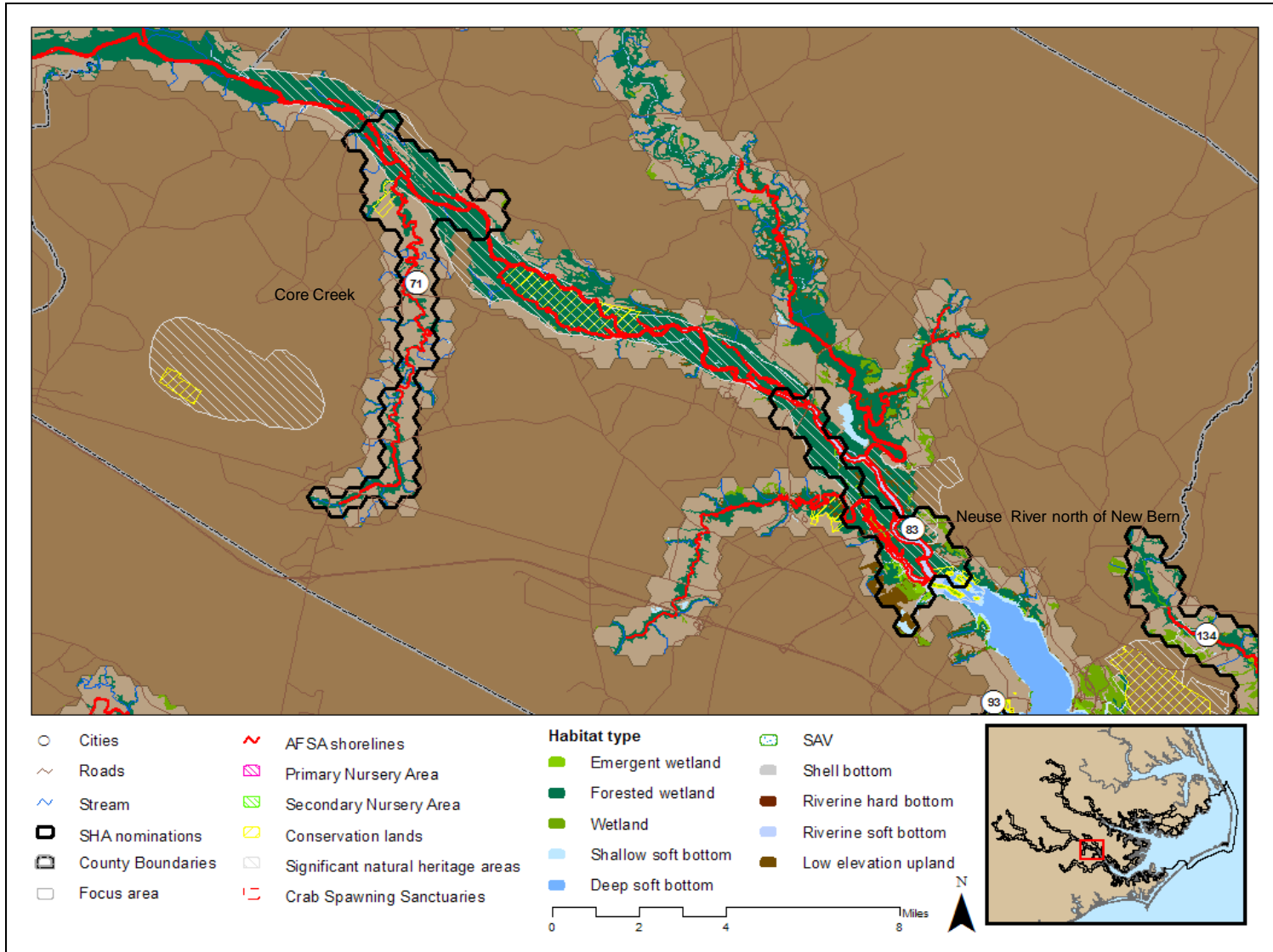
Map 10.17. Region 2 Strategic Habitat Areas (SHAs): Mid Neuse River including Dawson's, Adams, Hancock, and Clubfoot creeks (SHAs 105, 102, 104, 98, 113, & 112).
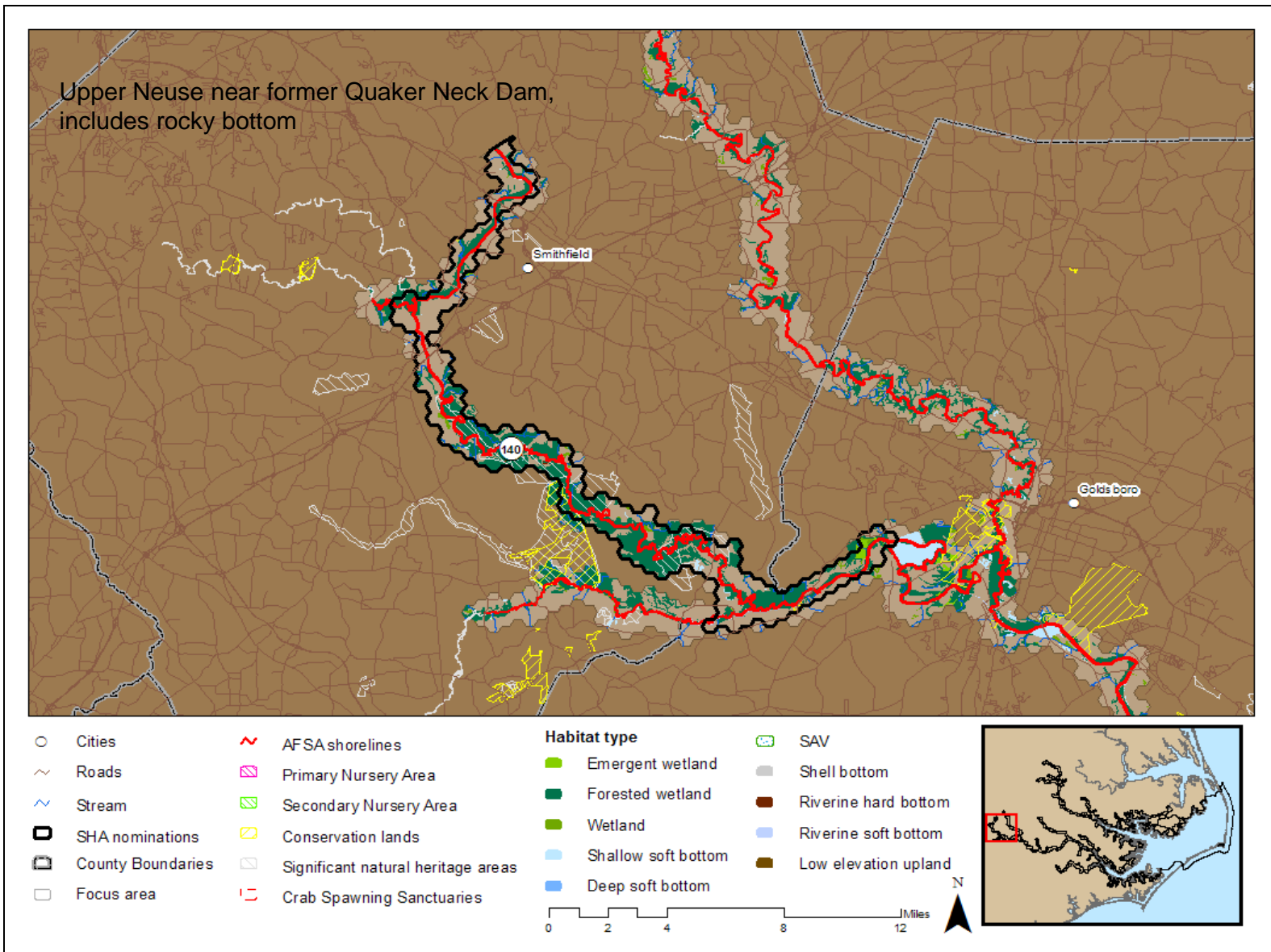
Map 10.18. Region 2 Strategic Habitat Areas (SHAs): Neuse River, New Bern area, including Trent River (SHAs 134, 99, & 93).

Map 10.19. Region 2 Strategic Habitat Areas (SHAs): Upper Neuse River and Core Creek (SHAs 83 & 71).

Map 10.20. Region 2 Strategic Habitat Areas (SHAs): Upper Neuse River, Goldsboro area (SHA 140).

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APPENDIX A: DATA/INFORMATION DIRECTORY

Regional (SHA) GIS File Structure on K:\fish\chpp\SHA related\Region 2\Inputs and outputs\[1]

1. R2_hydrologic_units
2. R2_sha_nominations
3. R2_subregions
4. R2_subregions_oregon_inlet_cut

Alteration factors

<u>Alteration</u> (The following is Jen Weaver's geodatabase containing the modified alteration files used in the analysis):

1. Conversions
    a. conv_by_hex
    b. trawling_updated
    c. uplands_to_ag
    d. uplands_to_dev
    e. wetlands_to_ag
    f. wetlands_to_dev
2. land_based
    a. anop_by_huc
    b. lu_by_huc
    c. marinas_over_10
    d. NPDES_by_huc
    e. Prohibited_shellfish_areas
    f. Slips_per_m_hu
    g. Waste_ponds
3. water_based
    a. canal_bb
    b. culvert_obstructed
    c. ditch_lines_focusarea
    d. drained
    e. dredged
    f. impounded
    g. mpra_danger_restricted
    h. seawalls
    i. storm_gate_obstructed
    j. water_based_merge
4. alt_habitat
5. hexagons
6. huc_boundaries
7. mines_per_hu
8. streams_by_hex

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[1] Files include only themes created specifically for SHA region 2 – other data sources can be clipped to SHA region from the coast-wide GIS (K:\Fish\Chpp\Coastwide data\).

Alteration tools (The following are ArcGIS version 10.0 custom toolboxes created by Jen Weaver that contain the GIS models used to create the alteration data layers listed above. Duplicate toolboxes are available for ArcGIS version 9.3.1 in the same folder (labeled 'Alteration tools 93')).

1. Alteration habitat processing
    a. Make riparian uplands
    b. Make riparian wetlands
    c. Make streams
2. Data processing
    a. Aggregate marinas by HU
    b. Aggregate point features by HU
    c. Calculate marinas per shoreline
3. Extent calculation
    a. Land-based extent
    b. Physical conversions extent
    c. Water-based extent

The following alteration files were created by Scott Chappell and may or may not have been used in the final analysis:

1. R2_altered_lulc_agri_by_nrt_polygons
2. R2_altered_lulc_dev_by_nrt_polygons
3. R2_altered_riparian_wetlands_lost_to_lulc_agri
4. R2_altered_riparian_wetlands_lost_to_lulc_dev
5. R2_animal_operations
6. R2_aquaculture_2009
7. R2_bottom_disturbing_fishing_gear
8. R2_canals_boat_basins
9. R2_canals_ditches_nhd
10. R2_converted_low_elevation_uplands
11. R2_culverts
12. R2_damsR2_ind_munic_waste_ponds
13. R2_lulc2001_by_hu
14. R2_NC_railroads
15. R2_NPDES_sites_hu
16. R2_nwi_impoudment
17. R2_possible_channelized_streams
18. R2_riparian_low_high_elv_uplands_lost_to_lulc_agri
19. R2_riparian_low_high_elv_uplands_lost_to_lulc_dev
20. R2_storm_gates_FWS
21. R2_upstream_impediments

Corroborating information

The following files were created by Scott Chappell and may or may not have been used in the final analysis.

1. 915_biodiversity_bysample
2. Biodiversity_pooled_spm
3. Prg120_biodiversity_nonnull
4. Prg120_cpue_all_onemin_trawls_nonnull
5. Prg120_pna_spp_nonnull
6. Prg915_abund_SpatialJoin

7. R2_corroboration_Oct2010_metadata
8. R2_dwq_impaired_waters_2010

MARXAN files

The following files were created by Scott Chappell and may or may not have been used in the final analysis.

1. R2_corroboration_Dec2010
2. R2_hexagons
3. R2_hexagons_focusarea
4. R2_MARXAN_clusters_Dec2010
5. R2_stage1_nominations_Dec2010

Natural Resource Targets

The following files were created by Scott Chappell and may or may not have been used in the final analysis.

1. R2_connected_wetlands
2. R2_intertidal_flats
3. R2_marine_intertidal_flats
4. R2_nrt_lines
5. R2_nrt_lines_focus_area
6. R2_nrt_polygons_focus_area
7. R2_riverine_estuarine_marine
8. R2_riverine hard bottom
9. R2_USACE_ReefBottoms

Final things (The following is Jen Weaver's geodatabase containing final SHA files):
1. Alterations
   a. R2_alteration_score
2. Boundaries
   a. map_index
   b. North_Carolina
   c. R2_boundary
   d. R2_focus_area_boundary
   e. R2_hexagons
   f. R2_hexagons_focus_area
   g. R2_hexagons_focusarea_habitatonly
   h. R2_hydrologic_units
   i. R2_subregional_index
   j. R2_subregions
   k. SHA_regions
3. Corroboration
   a. Corroboration_hex
   b. Hex_points_with_habitats
   c. SHA_nominations
4. Fish_data
   a. fish_values
   b. p120_all_cpue
   c. p120_biodiversity_pna

d. p195_fall_points
e. p1915_abundant_species_CPUE
f. p915_biodiversity
5. Habitats
    a. alteration_habitat_types
    b. PNAs
    c. R2_nrt_lines
    d. R2_nrt_lines_focus_area
    e. R2_nrt_polys
6. MARXAN
    a. MARXAN_output
    b. MARXAN_solution
    c. pu
    d. puvsp_habitats
    e. puvsp_lines
    f. puvsp_PNA
7. GP_2_abund
8. GP_3_abund
9. R2_waterbody_names
10. R2_waterbody_namesAnno
11. R2_waterbody_namesAnno2

R2_corroboration_Dec2010

Unit_id	Description	Coastwide	Region2 only
Area	Acres		
Ipna	Inland Primary Nursery Area	X	
Pna	Primary Nursery Area	X	
Sna	Permanent Secondary Nursery Area	X	
Afsa	Anadromous Fish Spawning Area	X	
Css	Crab Spawning Sanctuary	X	
Os	Oyster Sanctuary	X	
Ar	Artificial Reef	X	
Hb	Hard bottom (point)	X	
Orw	Outstanding Resource Waters	X	
Hydrounit	Hydrologic Units	X	
Snha_a	Significant Natural Heritage Areas (national)	X	
Snha_b	Significant Natural Heritage Areas (state)	X	
Snha_c	Significant Natural Heritage Areas (regional)	X	
Shoreline	Shoreline hexagons	X	
R1_sha	R1 SHA nominations		X
Pna_locked	PNA hexagon	X	
Canal_bb	Canals and boat basins		X
Culvert	Culvert obstructed		X
Impounded	Impounded		X
Lock	Lock obstructed		X
Dredged	Dredged	X	

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Unit_id	Description	Coastwide	Region2 only
Drained	Drained	X	
Military	Military impacts/ordinance	X	
Seawall	Vertical shoreline stabilization	X	
Wet_dev	Wetlands converted to development		X
Bottom_gea	Bottom disturbing fishing gear		X
Wet_ag	Wetlands converted to agriculture		X
Up_dev	Riparian uplands converted to development		X
Up_ag	Riparian uplands converted to agriculture		X
Waste_pond	Industrial waste pond		X
Shellfish	Shellfish closures	X	
Maj_npdes	Major NPDES	X	
Min_npdes	Minor NPDES	X	
Docks	Marinas and docks	X	
Maj_anop	Major Animal operations		X
Min_anop	Minor Animal operations		X
Cost_10_8	Total alteration		X
Eew	Estuarine emergent wetland	X	
Efw	Estuarine forested wetland	X	
Ehiw	Estuarine human impacted wetland	X	
Essw	Estuarine shrub/scrub wetland	X	
Esb6	Estuarine soft bottom (>6ft)		X
Esb03	Estuarine soft bottom (0-3ft)		X
Esb36	Estuarine soft bottom (3-6ft)		X
Esbnd	Estuarine soft bottom (ND)		X
Hw	Headwater wetland	X	
Hssav	High salinity SAV		X
Imsb	Intertidal marine soft bottom		X
Isbhd	Intertidal shell bottom (high density)	X	
Isbld	Intertidal shell bottom (low density)	X	
Lsbnb	Lacustrine soft bottmo (ND)		X
Leu	Low elevation uplands		X
Lssav	Low salinity SAV		X
Msb6	Marine soft bottom (>6ft)		X
Msb03	Marine soft bottom (0-3ft)		X
Msb36	Marine soft bottom (3-6ft)		X
New	Non-riparian emergent wetland	X	
Nfw	Non-riparian forested wetland	X	
Nhiw	Non-riparian human impacted wetland	X	
Nssw	Non-riparian shrub/scrub wetland	X	
Psbnd	Palustrine soft bottom (ND)	X	
Rew	Riverine emergent wetland	X	
Rfw	Riverine forested wetland	X	

Unit_id	Description	Coastwide	Region2 only
Rhiw	Riverine human impacted wetland	X	
Rhb	Riverine hard bottom		X
Rsb6	Riverine soft bottom (>6ft)		X
Rsb03	Riverine soft bottom(0-3ft)		X
Rsb36	Riverine soft bottom (3-6ft)		X
Rsbndl	Riverine soft bottom (ND) - lower		X
Rsbndm	Riverine soft bottom (ND) - middle elevation		X
Rsbndu	Riverine soft bottom (ND) - Upper		X
Ssbhd	Subtidal shell bottom (high density)	X	
Ssbld	Subtidal shell bottom (low density)	X	
We	Wetland edge	X	
Ns	Non-wetland shore	X	
She	Streams-high elevation		X
Sle	Streams-low elevation		X
Sme	Streams-middle elevation		X
Hbp	Hard bottom (possible)	X	
Sfg	Sound fish group (program 195)		X
Rfg	River fish group (program 195)		X
PNA_ac	PNA (acres)	X	
Selnom1	Scenario 1 nominations		X
SelFreq1	Scenario 1 frequencies		X
SelNom2	Scenario 2 nominations		X
SelFreq2	Scenario 2 frequencies		X
SelNom3	Scenario 3 nominations		X
SelFreq3	Scenario 3 frequencies		X
SelNom4	Scenario 4 nominations		X
SelFreq4	Scenario 4 frequencies		X
SelNom5	Scenario 5 nominations		X
SelFreq5	Scenario 5 frequencies		X
P915_richness	Program 915 fish species richness (avg)		X
P915_Diversity	Program 915 fish species diversity (avg)		X
P915_N	Program 915 sample size		X
P915_abund	Program 915 fish abundance (avg)		X
P120_richness	Program 120 fish species richness (avg)		X
P120_diversity	Program 120 fish species diversity (avg)		X
P120N	Program 120 sample size		X
AvgOfSou_flndr	Program 120 flounder abundance (avg)		X
AvgOfBl_crab	Program 120 crab abundance (avg)		X
AvgOfBrn_shrimp	Program 120 shrimp abundance (avg)		X
AvgOfSpot	Program 120 spot abundance (avg)		X
AvgOfAtl_croak	Program 120 croaker abundance (avg)		X

APPENDIX B: CALCULATING TOTAL ALTERATION

Alteration scores are calculated for each hexagon and take three things into account:

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 Table 2 were based on the individual habitat ratings for each threat listed in the threats table of the CHPP (Street et al. 2005, p. 486) and approved by the MFC, CRC, EMC, and DENR in 2004. This rating ranges from 0 (no impact) to 3 (high impact) and estimates the potential impact of each alteration factor for each habitat type. For water-based factors, such as trawling or dredging, the rating in the CHPP (Street et al. 2005, p. 486) was directly applied. For land-based alteration factors (i.e., land use/land cover), an adjusted S rating is applied to all hexagons within a 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 2 to get the adjusted severity for each particular alteration/habitat combination in each hexagon. An example is shown in table B-1. For example, if the severity rating for agricultural land use on SAV habitats is 2, and the hexagon lies within an HU with 40% cropland coverage where the maximum percent cover in the study area is 50 (0.80 intensity of alteration), the resulting S rating for that hexagon would be 2 x 0.80 = 1.60 (Table B-1).

Table B-1. Examples of calculating the adjusted S (severity) value for land-based factors.

Hexagon	% crop cover	Scaled intensity	Adjusted S in SAV
A	0	0	2 x 0 = 0
B	40	0.8	2 x 0.8 = 1.60
C	50 (maximum value)	1.0	2 x 1 = 2

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, such as dredging, the threat may only overlap with a portion of the habitat present. For land-based alteration factors, the E rating is simply 1 (complete overlap) for hexagons fully within a hydrologic unit.
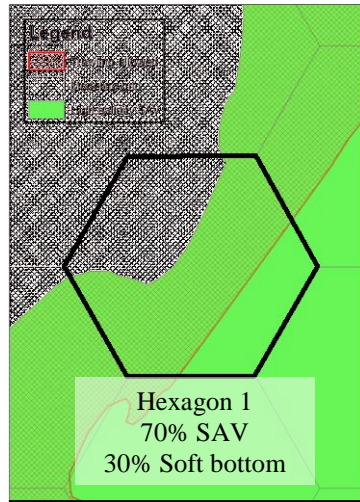
Figure B-1. Calculation of E rating for hexagon-based (water-based) alteration factors. Trawling (e.g., trawling, dredging).

Portion (P) ratings are calculated as [Acres of habitat X / Acres of all natural resource targets present within the hexagon].

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 – trawling, and contains 70 acres of SAV and 30 acres of subtidal soft bottom (Figure B-1, Table B-2). Within the 70 acres of SAV, trawling is allowed over 60% (E=0.6). The S rating of trawling on SAV is 2 (moderate) and the portion of SAV among targets in the hexagon is 70% or 0.7. The final rating for SAV would be S (2) x E (0.6) x P (0.7) = 0.84. Within the 30 acres of soft bottom, trawling is allowed over 100% (E = 1). The portion (P) of the soft bottom among targets in the hexagon is 30% or 0.3. The S rating for trawling on soft bottom is 1. The final rating for soft bottom is S(1) x E(1) x P(0.3) = 0.3. The total alteration of the hexagon would be 1.14 (0.84 + 0.30).

Table B-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$_{trawling}$	E$_{trawling}$	P	S x E x P	Total weight
Hexagon1	SAV	70	2	0.60	0.70	0.84	1.14
	Soft bottom	30	1	1.00	0.30	0.30	

Where more than one 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 B-3).

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

		S x E values				
Factor type	**Factors**	**Soft bottom**	**SAV**	**Wetlands**	**Shell bottom**	**Water lines**
Water-based	Culverts	0	0	2x0.2	0	2x0.5
	Dams/ impoundments	0	0	0	0	0
	Ditching/drainage/ channelization	0	0	2x0.2	0	0
	Forestry	0	0	0	0	0
	Boating activity	1x0.4	1x0.2	0	1x0.3	0
	Bottom trawling	1x0.5	2x0.5	0	2x0.2	0
	Navigation channels and inlet dredging	1x0.2	2x0.1	0	2x0.2	0
	Clam kicking	1x0.1	0	0	0	0
	Ports	0	0	0	0	0
	Conditionally approved closed	0	0	0	0	0
	Conditionally approved open	0	0	0	0	0
	Permanent closures	0	0	0	0	0
Land-based	Construction activities	0.02	0.04	0.06	0.04	0.1
	Cropland	0.1	0.2	0.2	0.1	0.5
	Development	0.06	0.18	0.06	0.18	0.45
Sum		1.38	1.82	1.12	1.42	2.05
Fraction of targets (P)		0.25	0.25	0.25	0.25	0.50
Sum x P		0.345	0.455	0.28	0.355	1.025
Total alteration for Hexagon 1		**2.46**				

PROCESSING DETAILS

For the region 2 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. Future changes could also include coding the alteration processing to be completely done in ArcGIS using the Python language.

All processing tools and data are provided in the alteration folder. This folder has four subfolders labeled data, docs, output, scripts, and scratch. It also includes the Alteration tools toolbox, which contains all of the ArcGIS tools described below. 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 9.3.1. ModelBuilder allows the user to string together 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 2 and the habitat types for alteration.

Alteration habitat type	NRT types
Creeks/rivers	Riverine hard and soft bottom
Deep soft bottom	All estuarine and marine soft bottom deeper than 6 feet
Interior wetland	All wetlands that are greater than 15 m from a shoreline
Riparian wetland	All wetlands within 15 m of a shoreline
SAV	Low and high salinity SAV
Shallow soft bottom	Soft bottom less than 6 feet in depth
Shell bottom	Subtidal and intertidal shell bottom
Stream	Polygons 4m in diameter centered on stream lines
Upland	Low elevation upland and land within 15 m of a non-wetland shoreline that is not identified as an NRT

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 NRT polygons by ALT_HABITA to get a feature class of alteration habitats (hereafter referred to as alt_habitat). 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. In order to run the tools, double click on the name. Right clicking and choosing 'edit' will allow you to see the full process diagram, which can be helpful if things need to be adjusted for future analysis.

1. DATA PROCESSING
These are miscellaneous tools that were used to create some of the inputs to alteration factors. They can be reused if need be but are provided more for convenience. Currently the tools are set to the input and output files that were used in the Region 2 analysis.

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. 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. The model is currently set for the animal operations layer, but it could be used for NPDES or any other point file as well.

Aggregate marines 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. The output is currently a feature class marinas_by_huc2 that is located in the alterations geodatabase under the land_based feature set.

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 shoeline in a HU in the field 'slips_per_m'.

2. ALTERATION HABITAT PROCESSING

These tools are all used in the initial steps of the alteration score calculation to manipulate the input features to make them compatible with the manner in which alteration scores are calculated. For example, the stream lines are converted to small polygons 4 meters in width centered on the stream line to calculate the overlap with most alteration factors. These tools manipulate the alterations habitat feature class, which is created by dissolving the NRT polygons by the field ALT_HABITA. It must have the attribute field 'ALT_HABITA', which contains the habitat type for alteration, for these tools to be effective. While not necessary, it is best to do these in the order they are presented below.

Make streams
Creates a streams polygon by adding a 2 m buffer to the steam lines in the study area and adds them to the NRT polygons shapefile.

Inputs: nrt polygons (with ALT_HABITAT attribute)
         nrt lines (with field EDGE, one of which is 'Stream')
Output: updated alt_habitat polygon file with "ALT_HABITAT" for the streams polygons labeled "STREAM"

Make riparian wetlands
This tool identifies and labels wetland areas within 15 m of a wetland shoreline as riparian. Prior to this all ALT_HABITAT was listed as interior wetlands for all wetlands.

Inputs: nrt lines file, or any file with wetland edges labeled with the attribute 'EDGE= Wetland'
        Alt_habitat polygons with all wetlands labeled as 'ALT_HABITA = interior wetlands'
Ouput: updated alt_habitat polygon file with riparian uplands included and labeled as 'Riparian wetland'

Make riparian uplands
This tool identifies all upland land within 15 m of a non-wetland shoreline not already in the polygon file as upland. THIS NEEDS TO BE RUN LAST.
Inputs: nrt line shapefile, with the wetland edge labeled as EDGE = Non-wetland
        alteration habitat shapefile, all polygons should have a value assigned for ALT_HABITA at this point
Output: updated alteration habitat shapefile with the additional riparian uplands labeled as 'upland'

3. EXTENT CALCULATION

These tools calculate 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, physical, and water-based alterations. This was done for this version because 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 for the purpose of alteration score calculation. These tools can be executed from the dialog box (by double clicking on the tool name). At this point, the alterations habitat file is assumed to be named alt_habitat and located in the alteration geodatabase.

Land-based extent
This tool joins the land-based alterations to a hydrologic unit file to create a master table of alterations by hydrologic unit. Shellfish sanitation areas and wasteponds are kept separate because they are not extrapolated to the hydrologic unit for the purpose of the alteration calculations. It 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 aggregated by HU. All of these are polygon feature classes except for the mines per HU input, which is a geodatabase table.
2. Polygon feature class of wastepond locations
3. Alteration habitats feature class
4. Hexagon boundaries, with hexagon ID
5. Hydrologic unit boundaries

Output: The following tables are output as DBFs:
1. hu_alt_factors_table.dbf: gives the amount of each alteration factor present by hydrologic unit

NC_VA_HU	12 digit hydrologic unit code
hu_area	Are of the hydrologic unit in square meters
maj_NPDES	Number of major NPDES sites per HU
min_NPDES	Number of minor NPDES sites per HU
maj_anop	Number of major animal operations sites per HU
min_anop	Number of minor animal operations sites per HU
dev_prop	Proportion of HU in developed land use
agri_prop	Proportion of HU in agricultural land use
mines	Log transformed total area of mining operations in the HU
marinas	Number of slips per meter of shoreline for each HU

2. hu_by_hex.dbf: gives the areas of each hydrologic unit in each hexagon and the max area of a hydrologic unit in each hexagon. This is used to calculate scores for hexagons that cover hydrologic unit boundaries.

NC_VA_HU	12 digit hydrologic unit code
hu_area	Are of the hydrologic unit in square meters
maj_NPDES	Number of major NPDES sites per HU
min_NPDES	Number of minor NPDES sites per HU
maj_anop	Number of major animal operations sites per HU
min_anop	Number of minor animal operations sites per HU
dev_prop	Proportion of HU in developed land use
agri_prop	Proportion of HU in agricultural land use
mines	Log transformed total area of mining operations in the HU
marinas	Number of slips per meter of shoreline for each HU

3. Wasteponds_by_hex_table.dbf: gives the area of waste ponds x habitat intersection for each hexagon

ALT_HABITA	Habitat type for alteration
ID	Hexagon ID
Shape_Leng	ArcGIS generated value for perimeter length
Shape_Area	ArcGIS generated value for shape area; area of waste pond/habitat overlap in square meters

4. shellfish_by_hex.dbf: gives the area of each hexagon that is comprised of closed shellfish waters and the habitats it intersects

ALT_HABITA	Habitat type for alteration
ID	Hexagon ID
Shape_Leng	ArcGIS generated value for perimeter length
Shape_Area	ArcGIS generated value for shape area; area of closed shellfish area/habitat overlap in square meters

Physical conversions extent
This tool combines the physical alterations into one feature class giving the presence/absence of each alteration and the area affected within each hexagon.

Inputs:
1. Alterations habitat feature class
2. Hexagons feature class, with hexagons labeled with a unique ID number (ID)
3. Polygon feature classes giving the areas affected by each of the 5 physical conversions:
    a. Upland converted to agriculture
    b. Upland converted to developed
    c. Wetland converted to agriculture
    d. Wetland converted to developed
    e. Trawling

Output:
Conv_by_hex.dbf: Each line represents a unique combination of hexagon, habitat, and alteration. The output is a table gives presence (1) or absence (0) of each alteration factor for each area described in the table. The field Shape_Area gives the area of each polygon overlap feature.

ID	Hexagon ID
ALT_HABITA	Alteration habitat type
wet_dev bottom_gea wet_ag up_dev up_ag	Identifies the alteration present. 1 for presence and 0 for absence.
Shape_Leng	ArcGIS generated value for perimeter length
Shape_Area	ArcGIS generated value for shape area
alt_area	Area of alteration/habitat overlap in square meters; should match Shape_Area

Water-based extent
Note: this makes 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. Ditches
    b. Drained wetland areas
    c. Dredged areas
    d. Storm gate obstructed areas
    e. Impounded areas
    f. Culvert obstructed areas
    g. Canals and boat basins
    h. Military areas
2. Line feature classes of areas affected by water-based alteration factors:
    a. Seawalls feature class
    b. Ditch lines feature class
3. Alteration habitats feature class
4. Hexagons feature class
5. NRT lines file

Outputs:
1. hab_alt_by_hex_table.dbf - Each line represents a unique combination of hexagon, habitat, and alteration. The output is a table gives presence (1) or absence (0) of each alteration factor for each area described in the table. The field Shape_Area gives the area of each polygon overlap feature.

ALT_HABITA	Habitat type for alteration
canal_bb culvert impounded lock dredged drained military	Identifies the alteration present. 1 for presence and 0 for absence.
ID	Hexagon ID
Shape_Area	Area of alteration/habitat combination in m^2

2. streams_by_hex_table.dbf – gives a list of the streams found in each hexagon, the length of the stream (Shape_leng)

ID	Hexagon ID
Shape_Leng	Length of stream feature, in meters
ID_1	Repeats the ID for ditches
ditch	1 for ditched streams, 0 otherwise
Shape_Le_1	Length of the ditch, if present
Prop_ditch	Proportion of ditched stream in each hexagon

3. seawalls_by_hex_table.dbf: Gives the amount of seawalls in each hexagon

EDGE	Type of line feature; should be Non-wetland for all
ID_1	Hexagon ID
Shape_Leng	Length of stream in hexagon, in meters
wall_len	Length of seawall in hexagon, in meters

4. shoreline_by_hex_table.dbf: lists the shorelines found in each hexagon

EDGE	Wetland or Non-wetland
ID_1	Hexagon ID
Shoreline	Length of shoreline in m

5. hab_by_hex_table.dbf

ALT_HABITA	Habitat type for alteration
ID	Hexagon ID
Shape_Leng	ArcGIS generated value for perimeter length
Shape_Area	ArcGIS generated value for shape area
hab_area	Habitat area in m^2; should match Shape_Area

R Tools for use in calculating alterations
These take the outputs of the previous steps (in ArcGIS) and use them to combine the severity, extent and portion into the alteration score for each hexagon. There are three separate scripts to calculate the severity x 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. The alteration severity file for region 2 is located at docs/alt_factor_ratings_final.csv. 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. The output directory is where the outputs of the script will be placed (currently the folder 'output'). 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 (found at line 9). 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 (hu_alt_factors.dbf, conv_by_hex.dbf or hab_alt_by_hex_table.dbf) 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.

Water based severity extent calculation.r
Input files:
1) Table listing the area-based alterations x habitat combinations per hexagon. Needs to have the fields:
    a. ALT_HABITA – alteration habitat type, must be one of the following: "Creeks/rivers", "Deep soft bottom", "Interior wetland", "Riparian wetland", "SAV" , "Shallow soft bottom", "Shell bottom", "STREAM", "upland"
    b. ID – unique hexagon identifier
    c. Shape_Leng – assigned for each feature class in arcGIS
    d. Shape_Area – assigned for each feature class in arcGIS; area of habitat in each hexagon
    e. alt_area - area of habitat intersection the by alteration factor in each hexagon
    f. Fields for any polygon based alterations considered. Currently I have these:
        i. "canal_bb" "culvert" "impounded" "lock" "dredged" "drained" "military"
        ii. each row gives the presence/absence (1/0) of one specific factor for each hexagon
        iii. each hexagon has multiple rows, one for each habitat type x factor combination

2) Table giving amount of each polygon habitat in each hexagon with the following fields:
    a. ALT_HABITA – alteration habitat type
    b. ID - unique hexagon identifier
    c. Shape_Leng - assigned for each feature class in arcGIS
    d. Shape_Area - assigned for each feature class in arcGIS
    e. hab_area – same as shape area

3) Alteration severity table
    a. Rows – habitat types (ALT_HABITA)
    b. Columns – alterations(must match names used in the alt file, are case sensitive as well
    c. Matrix of alteration x severity makes up the table

4) Raw file for length of seawalls by hexagon
    a. EDGE – identifier giving shoreline type, either "Wetland or "Non-Wetland"
    b. ID_1 – unique hexagon identifier

c. wall_len – length of seawall in hexagon

5) Length of streams with an amount ditched attribute. Necessary attributes:
    a. ID – hexagon identifier
    b. prop_ditch – proportion of stream ditched per hexagon (calculated in the arc script)

6) Length of shorelines in each hexagon
    a. EDGE – identifier giving shoreline type, either "Wetland or "Non-Wetland"
    b. ID_1 – unique hexagon identifier
    c. Shoreline – length of shoreline

Output: Severity multiplied by extent for all water based factors for each hexagon, in dbf and csv form: wbse.csv and wbse.dbf

Land based severity extent calculations.r
Input files:
1) Table of factors for each hydrologic unit (hu_alt_factors_table.dbf):
    a. NC_VA_HU – 12 digit hydrologic unit ID
    b. hu_area – area of hydrologic unit in meters
    c. Shape_Leng - assigned for each feature class in ArcGIS
    d. Shape_Area - assigned for each feature class in ArcGIS
    e. Currently the *unscaled* values for the affected amount for each HU:
        i. maj_NPDES – number of sites per HU
        ii. min_NPDES – number of sites per hu (includes aquaculture facilities)
        iii. docks - # of slips in marinas per m shoreline for each HU
        iv. maj_anop – number of sites per HU
        v. min_anop – number of sites per HU
        vi. dev_prop – proportion of area of each HU in developed land use class
        vii. agri_prop – proportion of area of each HU in agricultural land use class
        viii. mines – log of the area of mining operations present in each HU
2) Table giving amount of each polygon habitat in each hexagon (.dbf)
    a. ALT_HABITA – alteration habitat type
    b. ID - unique hexagon identifier
    c. Shape_Leng - assigned for each feature class in arcGIS
    d. Shape_Area - assigned for each feature class in arcGIS
    e. hab_area – area of habitat in meters; same as shape area
3) Table identifying which HU a hexagon is in (if a hexagon has more than one HU it will have more than one line):
    a. ID – hexagon ID
    b. NC_VA_HU – hydrologic unit
    c. hu_area – area of hydrologic unit
    d. Shape_Leng - assigned for each feature class in arcGIS
    e. Shape_Area - assigned for each feature class in arcGIS – area of hexagon in corresponding hydrologic unit
    f. FREQUENCY- number of HU's a hexagon intersects
    g. MAX_Shape_ - maximum area of hexagon in one HU
4) Alteration severity table:
    a. Rows – habitat types (ALT_HABITA)
    b. Columns – alterations(must match names used in the alt file, are case sensitive as well
    c. Matrix of alteration x severity makes up the table
5) wasteponds_by_hex_table.dbf - intersection of waste ponds with habitats in the study area
    a. ALT_HABITA – alteration habitat type
    b. ID – hexagon ID

      c.   Shape_Leng - assigned for each feature class in arcGIS

      d.   Shape_Area - assigned for each feature class in arcGIS (area in meters of the intersection)

6)   shellfish_by_hex.dbf – intersection of closed shellfish areas with habitats in the study area

      a.   ALT_HABITA – alteration habitat type

      b.   ID – hexagon ID

      c.   Shape_Leng - assigned for each feature class in arcGIS

      d.   Shape_Area - assigned for each feature class in arcGIS (area in meters of the intersection)

Output file: lbse.csv

Physical conversion severity extent calculations.r

Input files:

1)   Alteration severity table

2)   Physical conversions by hexagon table (conv_by_hex.dbf)

      a.   Each row represents a single combination of hexagon, habitat, and alteration. The hexagons are labeled in the field 'ID', the habitat is labeled in the field 'ALT_HABITA', and the alteration is designated by a 1 in the appropriate column. The field Shape_Area gives the area (in square meters) of the overlap for each row. The following alterations are currently included:

            i.   wet_dev –wetlands converted to developed land use

           ii.   bottom_gea – bottom disturbing gear

         iii.   wet_ag – wetlands converted to agricultural land use

         iv.   up_dev- uplands converted to developed land use

          v.   up_ag- uplands converted to agricultural land use

3)   Table giving amount of each polygon habitat in each hexagon (hab_by_hex_table.dbf)

      a.   ALT_HABITA – alteration habitat type

      b.   ID - unique hexagon identifier

      c.   Shape_Leng - assigned for each feature class in arcGIS

      d.   Shape_Area - assigned for each feature class in arcGIS

      e.   hab_area – area of habitat in meters; same as shape area

Output file: cbse.csv

Alteration scores.r

Combines the output of the previous three scripts to make the overall output

All inputs and outputs go to a folder called data in the working directory

Inputs:

1)   wbse.csv – severity by extent for water-based alterations

2)   cbse.csv – severity by extent for physical conversions alterations

3)   lbse.csv – severity by extent for land-based alterations. Note: this is already aggregated so that there's one row per hexagon whereas the other two severity by extent files are not.

4)   Table giving amount of each polygon habitat in each hexagon (hab_by_hex_table.dbf)

      a.   ALT_HABITA – alteration habitat type

      b.   ID - unique hexagon identifier

      c.   Shape_Leng - assigned for each feature class in arcGIS

      d.   Shape_Area - assigned for each feature class in arcGIS

      e.   hab_area – same as shape area

5)   Length of shorelines in each hexagon ("data/lines_by_hex_table.dbf")

      a.   EDGE – identifier giving shoreline type, either "Wetland or "Non-Wetland"

      b.   ID_1 – unique hexagon identifier

      c.   Shoreline – length of shoreline

Outputs (all of these currently go to the data folder):
1) alt_scores.csv, alt_scores.dbf - combined alteration scores for all hexagons. Includes hexagon ID [ID] and total alteration scores [r2_alt_sco]
2) pu.dat - Input file formatted for MARXAN (tab delimited and labeled correctly)
3) ind_scores.dbf - alteration scores broken down by alteration factor by hexagon. One line per hex gives the s x e x p for each alteration factor for each hexagon

APPENDIX C: INCORPORATION OF FISH ABUNDANCE DATA INTO THE MARXAN MODELING PROCESS

Fish abundance is important to include in the SHA designation process because it can reflect factors not otherwise included in the analysis that affect habitat quality. Fish abundance data was incorporated as corroborating data in the Region 1 nomination process because NCDMF's fishery independent sampling programs do not always follow a stratified random sampling design and lack the spatial coverage necessary for inclusion as a SHA target (NCDMF 2009). Unlike Region 1, fishery independent survey data with comprehensive spatial coverage is available for Region 2. Geographically, a large amount of the total area of Region 2 is the main body of Pamlico Sound, which shows little variability in habitat type or alteration score. Incorporating fish data into the MARXAN modeling process may provide an objective way to include abundance data and identify areas that are more important to fish production in an otherwise monotonous seascape.

The goal of this analysis was to create a data layer of fish abundance to use as an input to MARXAN. Specifically, it was thought that some areas labeled as 'estuarine soft bottom' could be more productive than others due to physical characteristics not captured by habitat data, such as currents or geographic location.

In order to create a data layer that could be incorporated into the MARXAN analysis, multivariate statistical techniques were used to identify groups of species that show similar patterns of occurrence based on abundance trends in Pamlico Sound and the lower portions of the major rivers. Multivariate statistical techniques were selected for the analysis because they allow for the incorporation of all species captured and reduce the amount of new data added into the modeling process, compared to adding all species separately. The resulting layers include species that are not recreationally or commercially fished, and may be important prey species for priority fish species. In addition, because they are not subject to direct fishing pressure, abundance of non-fished species may reflect true differences in habitat quality better than fished species. Once species groups were identified, geostatistical methods were used to create surfaces representing abundance of fish groups for the extent of the deep soft bottom habitats in region 2.

Methods

Fish were collected as part of the Pamlico Sound Survey (DMF program 195), which is a biannual trawl survey covering Pamlico Sound and the Neuse, Pamlico and Pungo Rivers. Samples were collected using a double rigged demersal mongoose trawl with 20 minute tows at 2.5 knots. All species are counted and measured; lengths and individual weights are recorded for a subset of more commonly occurring species. Sampling for the Pamlico Sound Survey usually occurs on the second and third week of June and September of each year, though sampling can often run longer due to weather delays. Survey methods have been consistent since 1991. Data collected from 1991 – 2008 samples were used for this analysis. Within each sampling period, 52-54 samples were collected. The sampling area is divided into seven strata, each with a minimum number of samples (in parentheses): Neuse River (5), Pamlico River (5), Pungo River (3), Pamlico Sound East (3 shallow, 3 deep) and Pamlico Sound West (3 shallow, 3 deep).
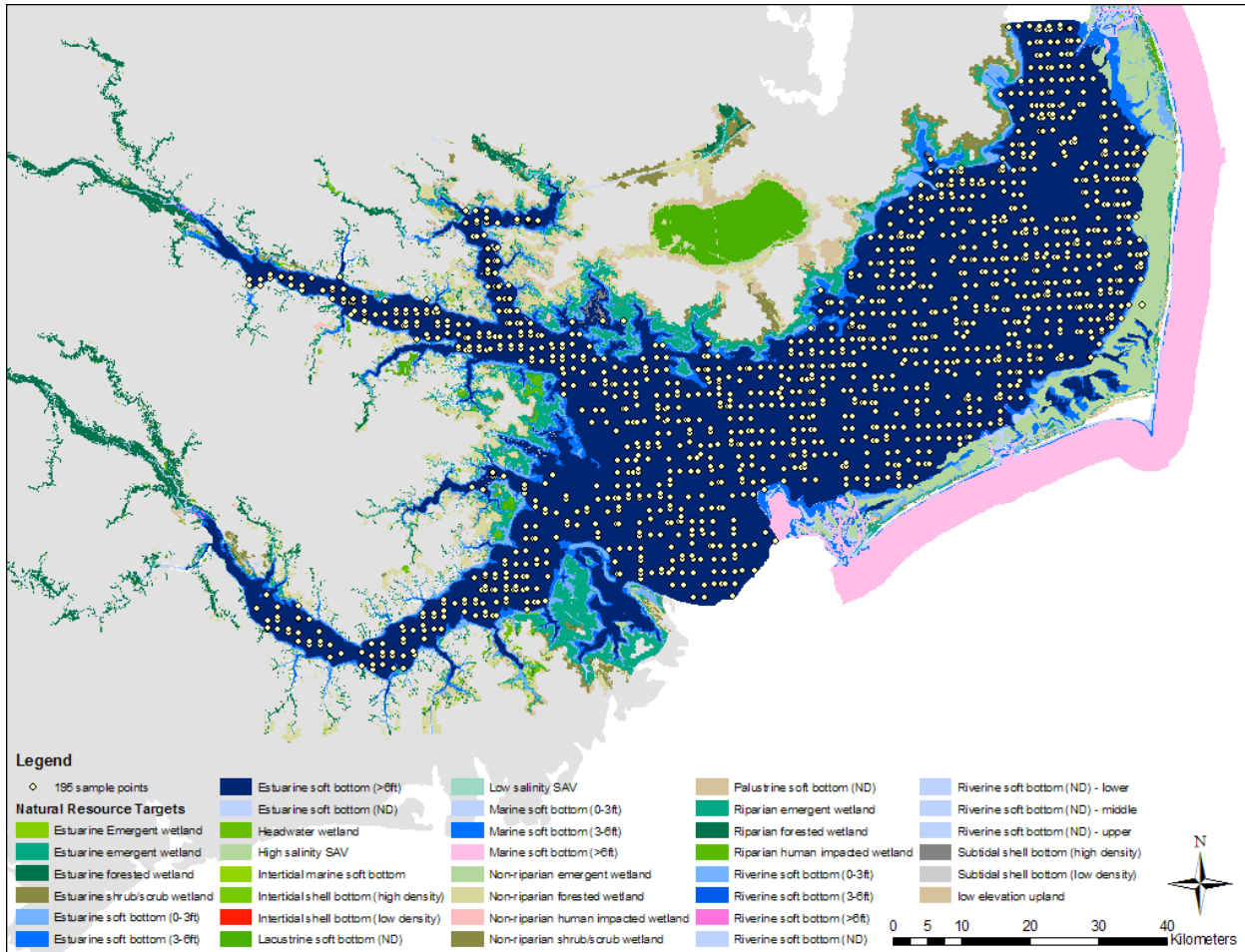
Figure 1: Map of program 195 sampling sites in region 2

Preliminary analyses and previous studies indicated a seasonal difference in estuarine fish assemblages (Ross & Epperly 1985), so analyses were done separately for fall and spring samples. After examining the results, the priority species identified for the Region 2 analysis were found mostly to occur in the fall samples, so analyses were focused on fall sampling data. Data were filtered to remove incomplete records or points with erroneous geographic coordinates. After filtering, the dataset consisted of 991 samples. Species that did not occur in more than 5% of the samples were removed, leaving 49 possible species to consider for community analysis.

Heirarchical cluster analysis was used to identify species with similar trends in abundance. Cluster analysis forms groups out of input units in a manner that minimized dissimalirity among the data. The process begins as the least dissimilar species are joined together to form a group. Once a group has been formed, dissimilarities are recalculated and a new grouping is made. This continues until all of the units of analysis have been joined into one group. The resulting structure is shown in a dendrogram, which displays the group associations relative to the amount of information lost by forming each connection. The less information lost, the more alike the group members are. Following the approach of Shertzer & Williams (2008), a double square root transformation was used, which reduces the effect of large abundances on similarity between sites and transforms the abundances into nearly presence/absence (McCune and Grace 2002). Bray-Curtis dissimilarity (Sorenson distance) was used to compute dissimilarity as it has been proven to give interpretable results in ecological studies and has been widely

applied to studies of fish assemblages (Shertzer & Williams 2008). All analyses were performed in PC-ORD (McCune and Mefford 1999), using the hierarchical clustering function.

Interpolation
Kriging interpolation was used to create a continuous surface of fish abundance values. Kriging differs from simpler interpolation methods because it accounts for error around observed points instead of creating surface that reflects the exact measured abundance at each location. Surfaces were created using the geostatistical analyst toolset in ArcGIS 9.3 (ArcGIS, Version 9.3; ESRI, Redlands, CA, USA), which allows the user to interactively fit and examine different models. Abundance for all group members was summed, and the natural logarithm of the summed abundance of all species for each group was used as the input for interpolation. Universal kriging was applied for each dataset because it allows for detrending. Total abundance was log transformed to meet the assumptions of the Kriging, which assumes a Gaussian error structure among the dependent variable. Anisotropy was present in both datasets, and modeled accordingly. Cross validation was used to examine the resulting model fits and to compare between models. The mapped results were also examined to ensure that the resulting models were appropriate. A raster of predicted values for each fish group across the study area was created, and used as the basis for the MARXAN input layer.

Creation of MARXAN input data
In order to get an input layer for use in MARXAN, the resulting grids were clipped to the extent of habitats labeled as estuarine deep soft bottom. Values were assigned to each hexagon for each fish group by identifying the value for each fish surface at the centroid of each hexagon in the planning unit. To derive a representation level for each fish group, the total amount in the study area was summed, and the desired percentage of the total was set as the representation level for each fish group.

Results
Outputs from the cluster analysis indicated that there data were split into two major groups (Figure 2). One consisted mostly of rare and incidental species that were not of interest to this project. The other group was split into four subgroups, two of which contained the species most important for the SHA process. It was decided to use these groups as the basis for creating a data layer of fish abundance. The spatial data indicates that one group is widely abundant throughout both the sound and the rivers, while the other is abundant only in Pamlico Sound.
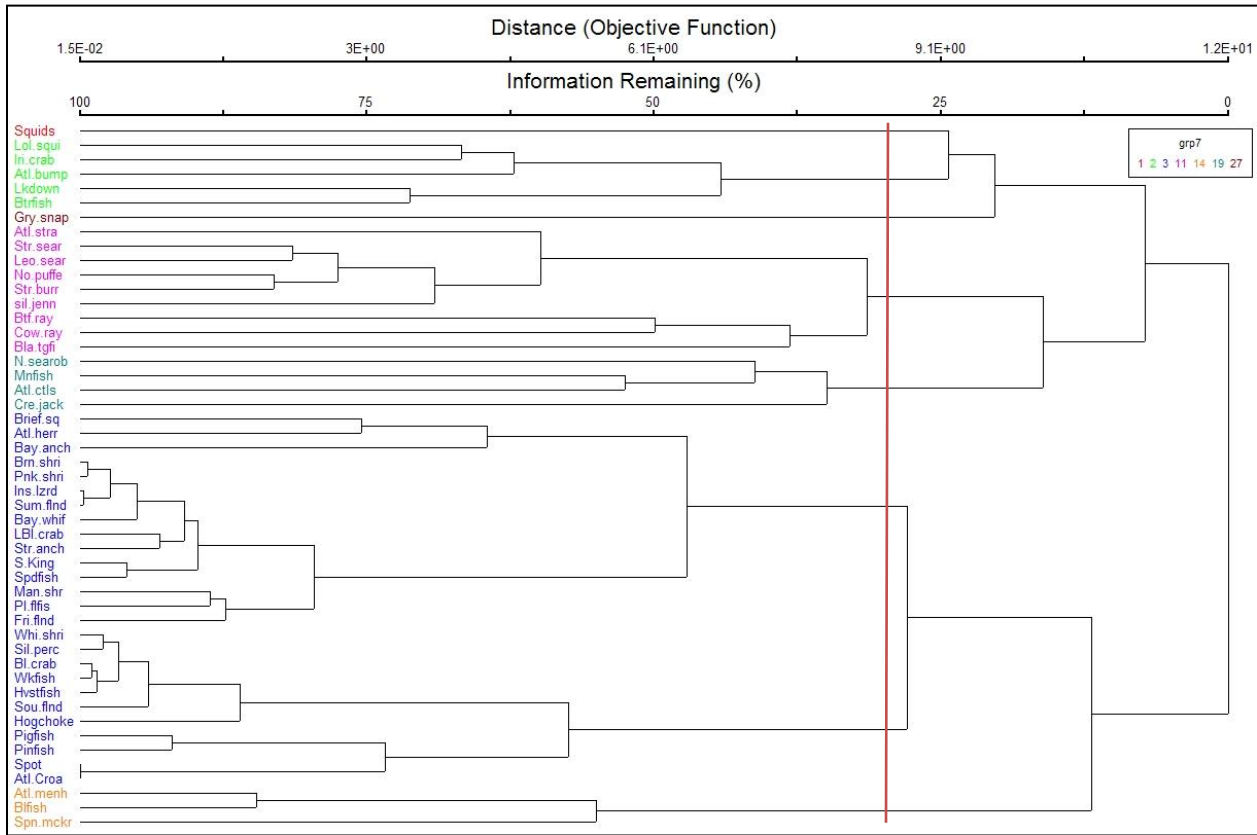
Figure 2: Output dendrogram from cluster analysis. Red line indicates where the tree was cut into groups.

Table 1. Species composition of the two fish abundance groups

Group 2 (River)	Spot, Croaker, Pinfish, Pigfish, Hogchoker, Southern flounder, Harvestfish, Weakfish, Blue crab, Silver perch, White Shrimp
Group 3 (Sound)	Fringed flounder, Planehead filefish, Mantis shrimp, Spadefish, Southern kingfish, Striped anchovy, Lesser Blue Crab, Bay whiff, Summer flounder, Inshore lizardfish, Pink shrimp, Brown shrimp

Interpolation was conducted for each of the two groups separately. Input parameters are shown in table 2. The interpolated surface for this group was fit using universal Kriging with a third order trend, which provided the best fit based on visual examination of the diagnostic plots. Abundance for the river group was highly variable, making the model difficult to fit. The model underpredicts the higher abundances and overpredicts the lower abundances, which is a common result of Kriging interpolation. Because kriging interpolation is dependent on correctly capturing the error structure, it is important that the prediction errors match the variability in the input dataset. Standardized mean prediction error was low (0.0292) indicating that overall the model was unbiased. QQ plots of the standard errors indicate that they are normally distributed, and similar to those from the observed data (standardized RMS 1.089). Average standard error (4.093) is higher than RMS (1.911), indicating that the model overestimates variability compared to the observed values. This can be seen in the predicted values, a few of which are far outside of the range of the observed data. The output interpolation map is more variable than the sound group because of the selection of a third order trend (figure 3). There are some extreme predictions at the edges of the map, outside of the area that was actually sampled. These were eliminated in the final layer by restricting the range of the output values to between 0 and 10. The range of input values was 0-9.05.

The sound group interpolation was fit with a first order trend, and is a better fit than the river group. There is still a general trend to overpredict points of low abundance and underpredict areas with high

abundance. Mean standard prediction error is close to zero (-0.019), indicating that the model is unbiased. Prediction errors appear to be normally distributed and average standard error (0.878) is similar to RMS (0.9718), indicating that modeled variability is similar to observed variability. The resulting surface has low abundance in upper reaches of the rivers, higher abundance in the middle of the sound, and some areas of extremely high abundance on the eastern edge of the sound that are probably prediction error. The range of the predicted values is -0.4 to 5.7, which is comparable to the input data points (0-5.61). Values below zero were converted to zeroes for the purpose of the MARXAN analysis.

Table 2. Input specifications for kriging interpolation of both fish groups

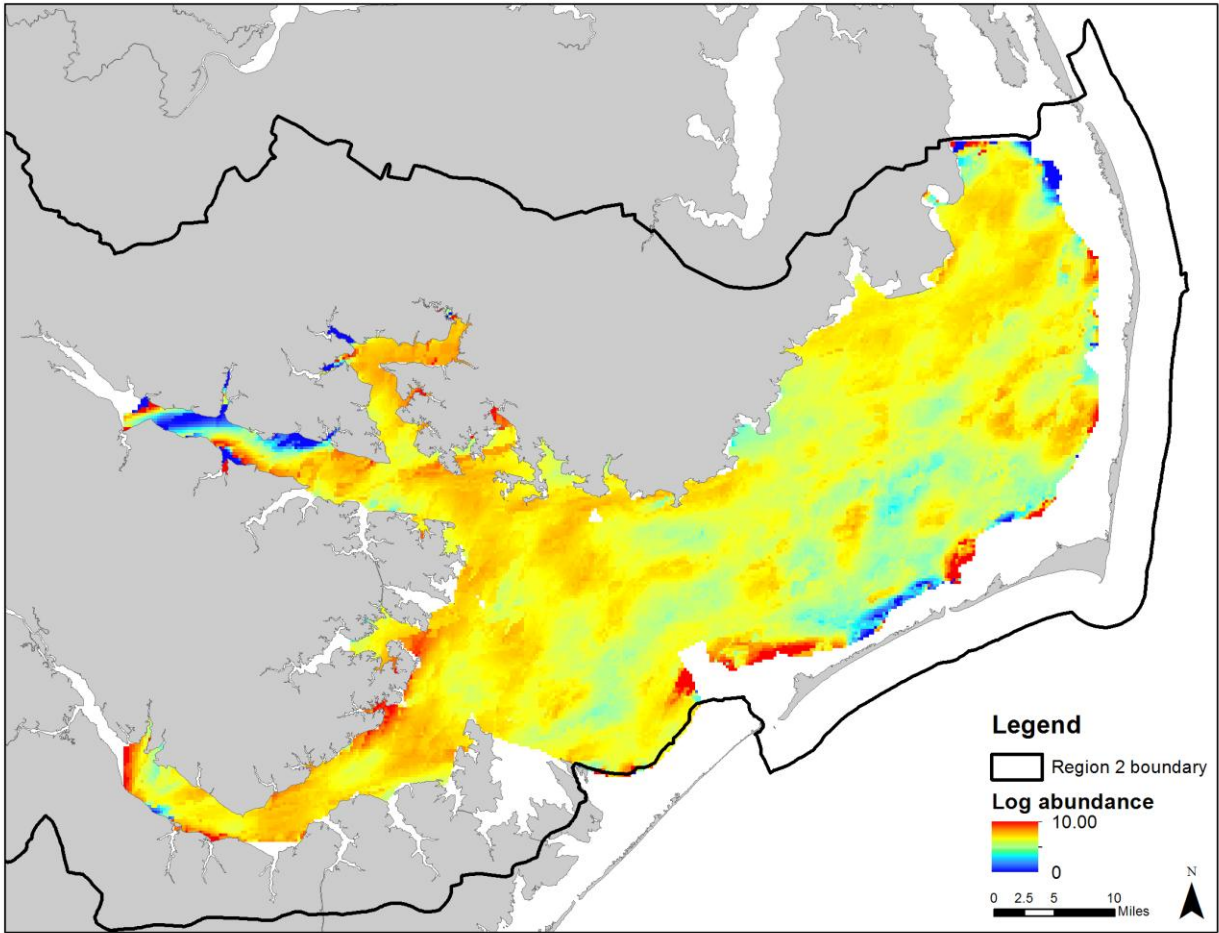|	Sound Group	River Group
Method	Universal Kriging	Universal Kriging
Output type	Prediction	Prediction
Trend type	1	3
Neighbors to include	5	5
Include at least	2	2
Sector type	Four and 45 degree	Four and 45 degree
Angle	43.78	47.41
Major semiaxis	54350.985	123575.29
Minor semiaxis	37261.222	68941.32
Trend removal	Global polynomial interpolation	Local polynomial interpolation
Power	1	1
Variogram	Semivariogram	Semivariogram
Number of lags	12	12
Lag size	4770.3	10883
Nugget	0.675114554	1.303
Measurement error	0	0
Model type	Spherical	Spherical
Range	54350.985	123575.29
Anisotropy	Yes	Yes
Minor range	37621.222	68941.32
Direction	43.78	47.41
Partial sill	0.532	0.398

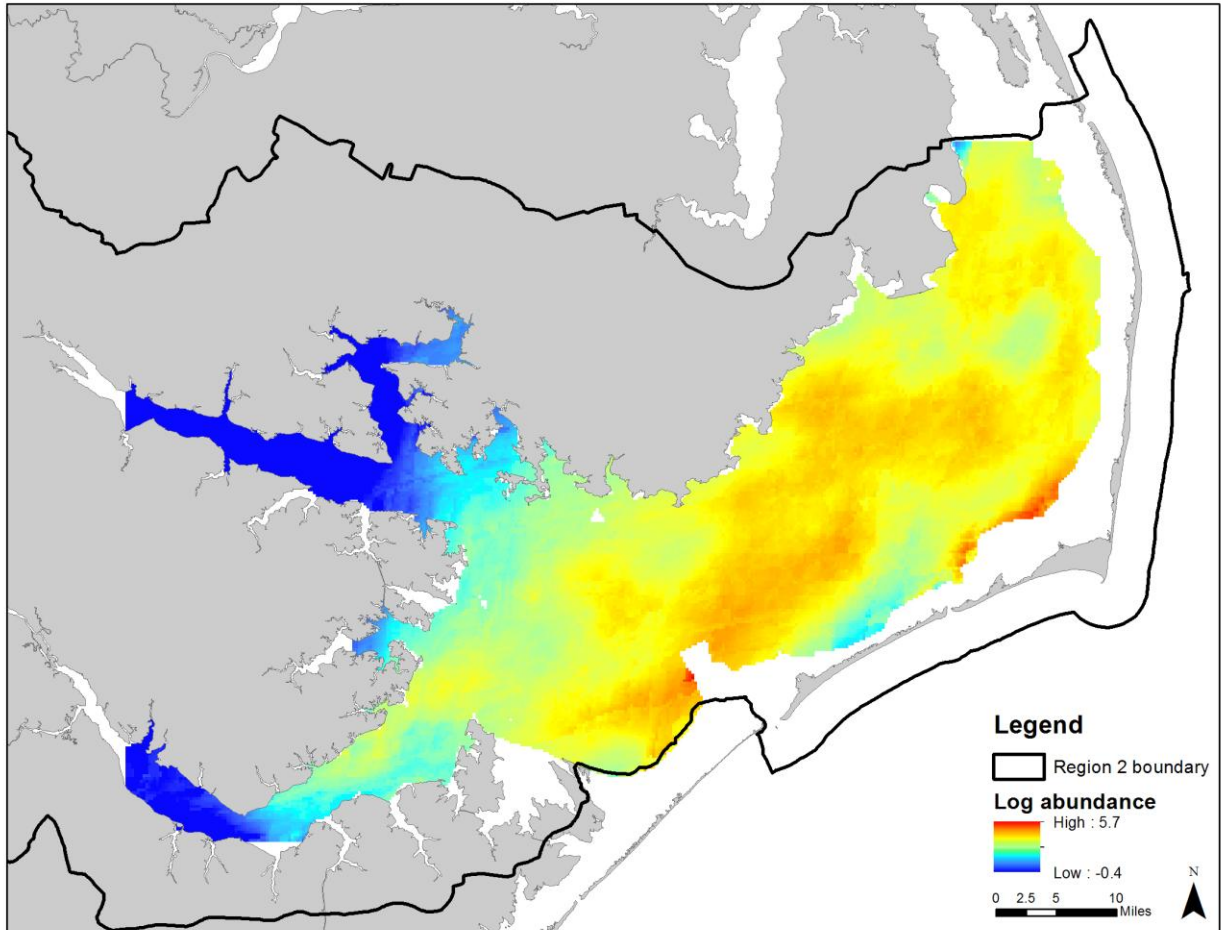**Figure 3: River group interpolation**

Figure 4: Sound group interpolation

Discussion

Abundance data is highly variable and hard to model. While not perfect, the method used to create the fish data layer provides a way to incorporate fish abundance into the MARXAN planning process, and to visualize the trends in fish abundance throughout the region. Other options for creating a layer in MARXAN would include creating habitat models of either presence/absence or predicted CPUE. However, these are more time-intensive to produce and require having comprehensive coverage of abiotic variables for the study area, which were not available. Interpolation presents a second option for creating a surface layer of fish abundance, and is relatively easy to create using the tools available in the Geostatistical Analyst (ESRI 2009). Bahn and McGill (2007) argue that, due to the importance of spatial structure and presence of autocorrelation in determining species distribution, interpolation can outperform niche-based modeling at larger scales.

The development of a fish group layer allowed the SHA advisory committee to examine available fishery independent data as part of the MARXAN planning process. The inclusion of the fish values in the MARXAN selection process forced the program to select areas in the middle of the sound as part of the MARXAN solution. While many of these areas were eliminated because they were isolated and small by the committee during selection, the committee did choose certain areas as fish hostpots near the mouths of the Neuse and Pamlico Rivers and across some of the shoal areas adjacent to shoreline features.

Literature Cited
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Ecology and Biogeography **16**, 733–742 (2007).

ESRI. 2009. ArcGIS Desktop: Release 9.3. Redlands, CA: Environmental Systems Research Institute.

McCune, B. and Grace, J.B. 2002. *Analysis of Ecological Communities*. MjM Software Design: Gleneden Beach, OR.

McCune, B. and M. J. Mefford. 2006. PC-ORD. Multivariate Analysis of Ecological Data. Version 5.13 MjM Software, Gleneden Beach, Oregon, U.S.A.

North Carolina Division of Marine Fisheries (NCDMF). 2009. *Strategic Habitat Area Nominations for Region #1: Albemarle Sound to Northeastern Coastal Ocean of North Carolina*. North Carolina Division of Marine Fisheries: Morehead City, NC, 91 pp.

Ross, S.W. & Epperly, S.P. 1985. Utilization of shallow estuarine nursery areas by fishes in Pamlico Sound and adjacent tributaries, North Carolina. *Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration* 207-232.

Shertzer, K.W. & Williams, E.H. 2008. Fish assemblages and indicator species: reef fishes off the southeastern United States. *Fishery Bulletin* **106**, 257-269.

APPENDIX D: 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 2.1.1 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 I used to crossreference 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.

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 2, this was made in Excel and exported to a csv.

   Example species file:

id	target	name	spf
1	0	Emergent_wetland	100
2	0	Est_shrubscrub_wet	100
3	0	Est_soft_bottom_deep	100
4	100625213.3	Est_soft_bottom_shallow	100
5	63340840.9	Est_soft_bottom_mid	100
6	994230.1102	Est_soft_bottom_ND	100
7	56165054.07	Forested_wet	100
8	11604155.83	Headwater_wet	100

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 and Region 1 SHA nominations 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 units shapefile, and exported to a csv.

   Example planning unit file:

id	cost	status
1	0	0

2	0	0
3	1.024817	0
4	1.160994	0
5	0.767445	0
6	1.091048	0
7	1.115639	0
8	0.140693	0
9	1.189066	0
10	0.737211	0
11	1.385543	0

3) Boundary file (bound.dat) – This gives the length of the boundary between adjacent files. It is in the format of id1, id2, and amount. For the region 2 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	3	440
1	4	440
1	19140	440
2	3	440
2	5	440
2	6	440
2	19140	440
3	4	440

4) Planning units vs. Species file (puvspr.dat) – This file gives the amount of each conservation feature in each planning unit. MARXAN version 2.1.1 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 (r2_nrt_polygons) and line (r2_nrt_lines) habitat shapefiles. Fish group values were obtained by identifying the value at each hexagon centroid. 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
7	1	3032.72
7	2	34301.95
7	3	182339.9

29	3	69.95
32	3	251.47
33	3	583.5
7	4	92544.15
33	4	818.69

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.

MARXAN resources:

Watts, M. E., R.R. Stewart, D. Segan, L. Kircher: Using the Zonae Cogito Decision Support System, a Manual.pdf (1288KB)

Marxan
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.

Marxan with Zones
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.

APPENDIX E: SENSITIVITY ANALYSIS

MARXAN allows the user customize the selection algorithm by adjusting several parameters. In order to ensure a robust analysis, these parameters should be calibrated for each analysis to ensure that MARXAN is meeting the objectives of the project (Ardron et al. 2008). Calibration involves running the analysis with a range of values and examining the outputs. Two parameters were examined in this sensitivity analysis: the number of runs and the boundary length modifier (BLM).

Number of runs
MARXAN is an iterative program that proceeds for a user defined number of runs and returns the best solution it found across all runs. Each run will continue for a user-defined number of iterations, in each of which a different solution is considered. MARXAN compares solutions by calculating a score for each potential configuration of reserves. For each run, the program continues to evaluate new solutions until the program ceases to find new solutions with lower scores, or the number of iterations is reached. The assumption behind this is MARXAN will find the best solution, or something very close to it, in the user-defined number of runs. There is no guarantee that this solution will be the best solution of all possible for the analysis. As the number of runs is increased, it is more likely that MARXAN will find a better solution. The total number of runs for the previous SHA region was set at 100 because processing time was quite lengthy; however, in this analysis a newer version of MARXAN was used and the extent of the data that was included for MARXAN analysis was decreased by only including hexagons in the focus area. These changes greatly decreased the processing time, allowing for the addition of number of runs in this analysis.

In this analysis the distribution of scores across all MARXAN runs for an analysis with 100 runs and an analysis with 500 runs were examined, specifically with respect to the lower scores. The score for each run is given in the MARXAN output tables ending in '_sum.txt'.

Upon inspecting the initial solutions with 100 runs, the scores of the best solutions were sometimes much lower than that of the second best solutions, leading to a distribution that is truncated at lower scores (Figure 1). This indicates that MARXAN might not be finding the best solution possible, and could, in fact be finding a local minimum instead of a global minimum. The distribution of scores that result from an analysis with 500 runs is more robust among lower scores, indicating that MARXAN is finding similar solutions across runs. MARXAN is, therefore, more likely converging to the best solution to the problem across all of the runs. Increasing the number of runs only resulted in a moderate increase in processing time (~ 5 minutes compared to ~ 2 minutes for 100 runs). Based on these results, the number of runs was set to 500 for the rest of the analysis.
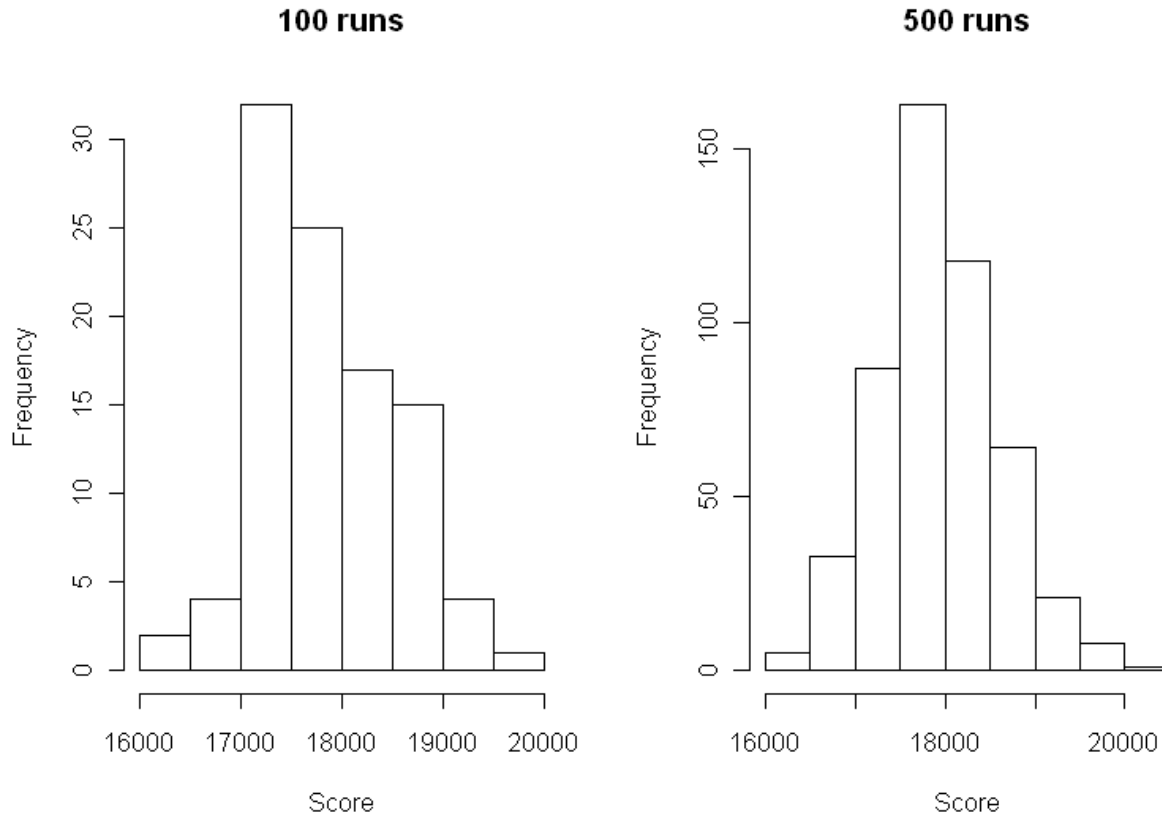
Figure 5: Distribution of scores for MARXAN analysis using 100 and 500 runs

Boundary Length Modifier

MARXAN computes an objective score for each potential solution that is the sum of three components: a cost component that sums the cost of the planning units included, a species protection component that computes a penalty for not reaching species representation goals, and a boundary length component that penalizes a solution for being more spread out (having more boundary length). The total score for each run is the sum of all three components; therefore, the components all need to be on a similar scale in order for the solution to consider all three factors in the solution. If the components are not scaled, the program will be selecting solutions based on changes in one component and not the others.

Each component has a parameter that can be adjusted to adjust its scale. The species component is based on a species penalty factor that is assigned to each species. The boundary term is the sum of the boundary length multiplied by a boundary length modifier (BLM), which should be adjusted based on the units of the analysis. The cost can be adjusted by rescaling the units of the cost score. I examined the influence of the three different parameters on the MARXAN solutions in order to ensure that the MARXAN analysis was equally considering all three parameters. In order to assess the contribution of each component to the final score, scatterplots were created to visualize the relationship between the total score and each component across all 500 runs. Values for the score, cost, boundary length and species penalty were taken from the MARXAN summary output table (ending in _sum.txt) created at the end of each analysis. In addition, maps of the best solution and selection frequency were examined to visualize the spatial arrangement of the solutions produced at each setting.

Boundary length factors into the equation by summing the length of the boundary of each solution and multiplying it by a boundary length modifier. The boundary length modifier (BLM) can take on any value and should be adjusted to scale the boundary length to the other terms in the score equation. For example, an analysis in which the boundary lengths are expressed in meters would require a BLM that is

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one thousandth that of an analysis that expresses the same boundaries in kilometers in order to yield the same scores. The BLM for SHA analysis was originally set to 0.01 based on visual examination of results. This analysis examined the effect of lowering the BLM on the relationship between the overall score and its components, and the spatial configuration of the final solution. BLMs of 0.001 and 0.005 were considered, in addition to the original value of 0.01.

At the initial BLM of 0.01, there was a strong correlation between boundary length and score for each run and no correlation between cost and score (Figure 3). This indicates that the MARXAN selections are being driven by differences in boundary length and not in overall cost. The expanses of open water connecting the shorelines of the Neuse and Pamlico River support this conclusion (Figure 2). Decreasing the BLM yielded a solution that was more spatially separated and had more numerous small areas in the solution network. At a BLM of 0.005, the scatterplots indicate that there is a still a tight relationship between the BLM and the total score (Figure 5). Lowering the BLM again to 0.001 the relationship between the score and the BLM is not as strict and there is a positive relationship between the cost and score, indicating that changes in score correlate to changes in cost (Figure 7). As expected, the solution is more fragmented than at higher BLMs. Fragmentation was more pronounced in Pamlico Sound, where the solution produced many isolated areas compose of three or fewer clusters in response to the fish group targets. Shoreline areas remained relatively aggregated; suggesting that the extra boundary length allowed was used to add areas in the sound that were based on the fish targets. The relationship between SPF and total cost indicates that not all representation levels were met in all analyses. Upon further examination, these targets were not far from being met, so it was decided not to base decisions on this factor, as modifications would likely change the representation of habitat types in the proposed SHA network during corroboration.

Based on this information, the advisory group decided to use the solution with a BLM of 0.001 as the basis for the corroboration phase of the analysis, but to only consider clusters that were greater than 3 hexagons as potential SHAs.
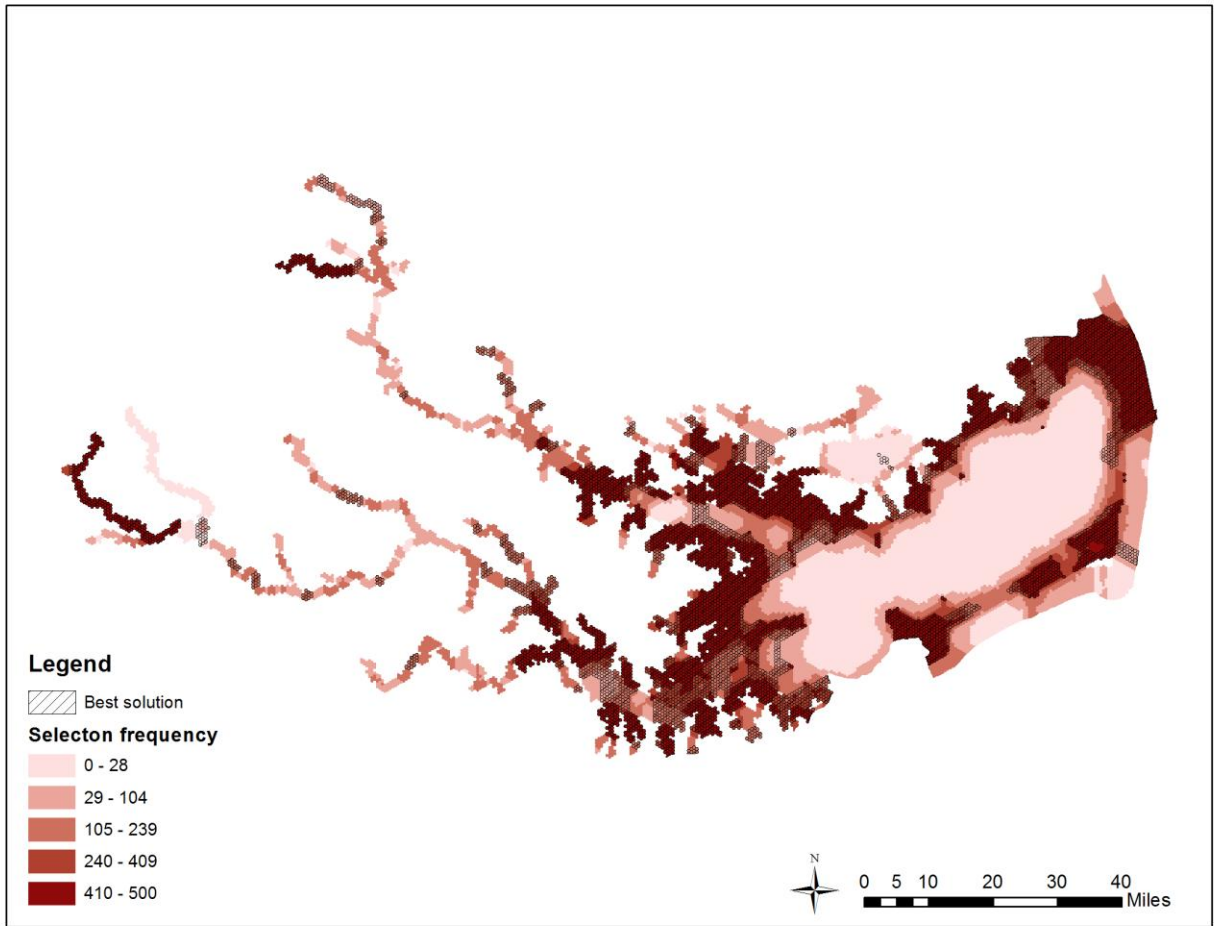
Figure 6: BLM 0.01
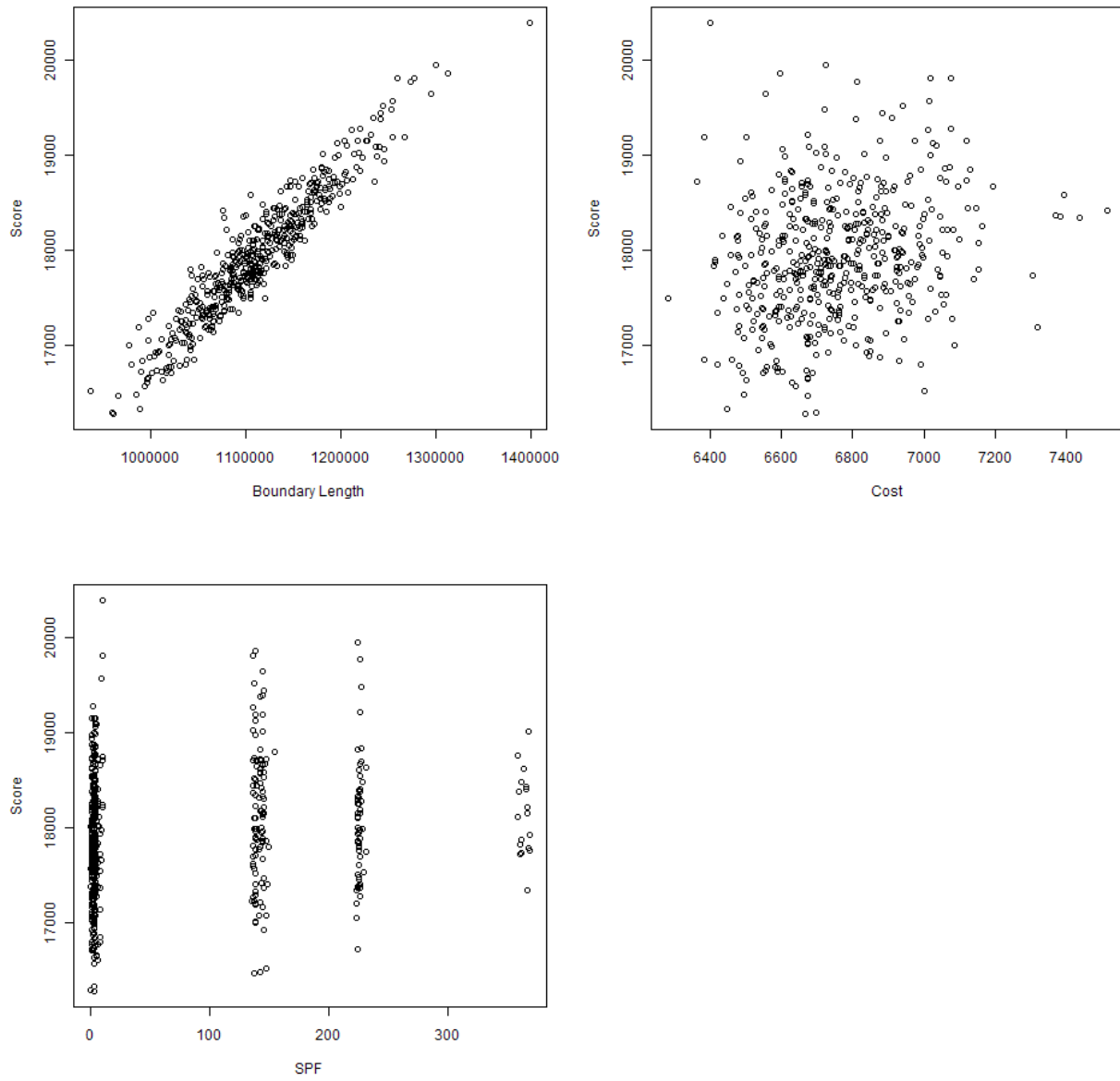
Figure 7: Correlation graphs for initial setup, BLM = 0.01 and 500 runs
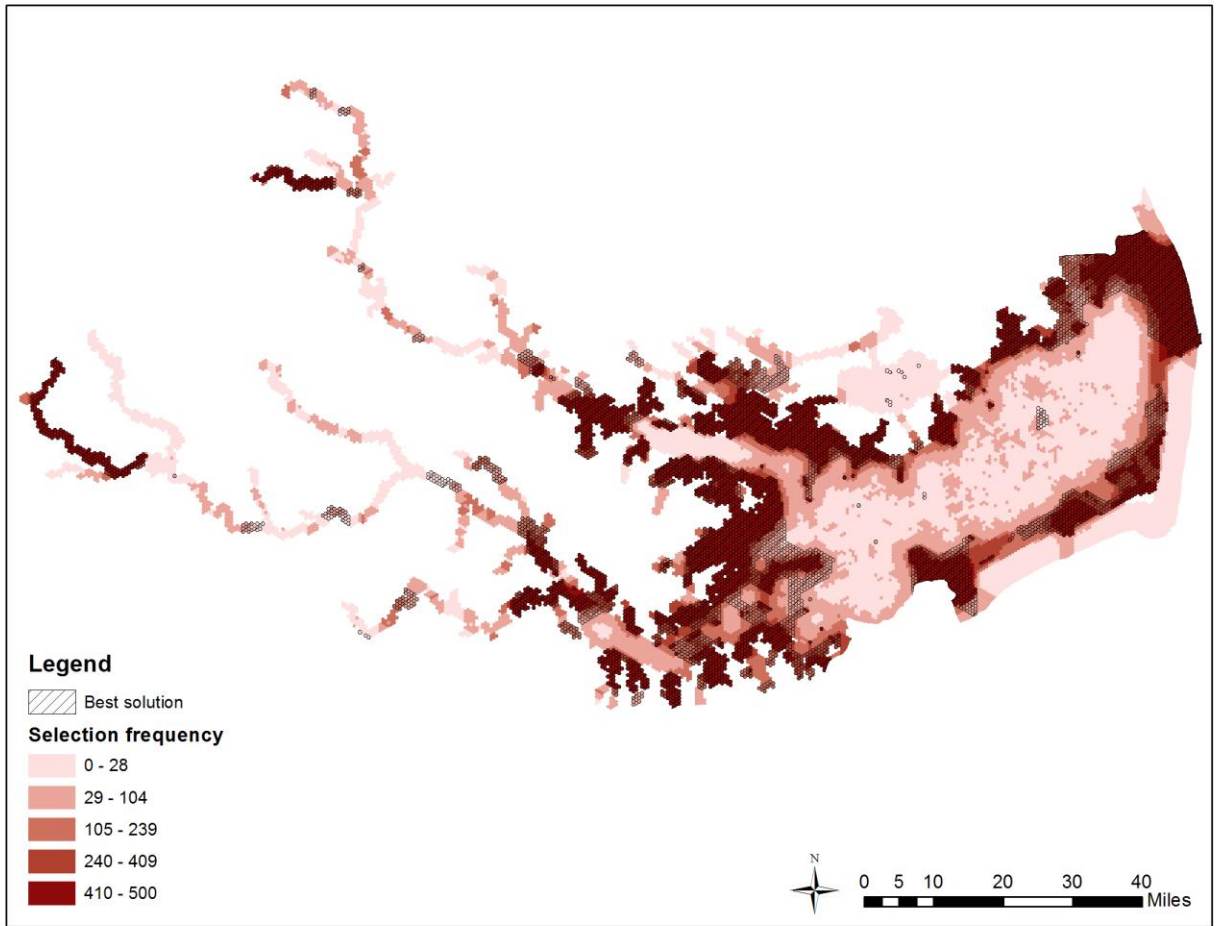
Figure 8: BLM of 0.005
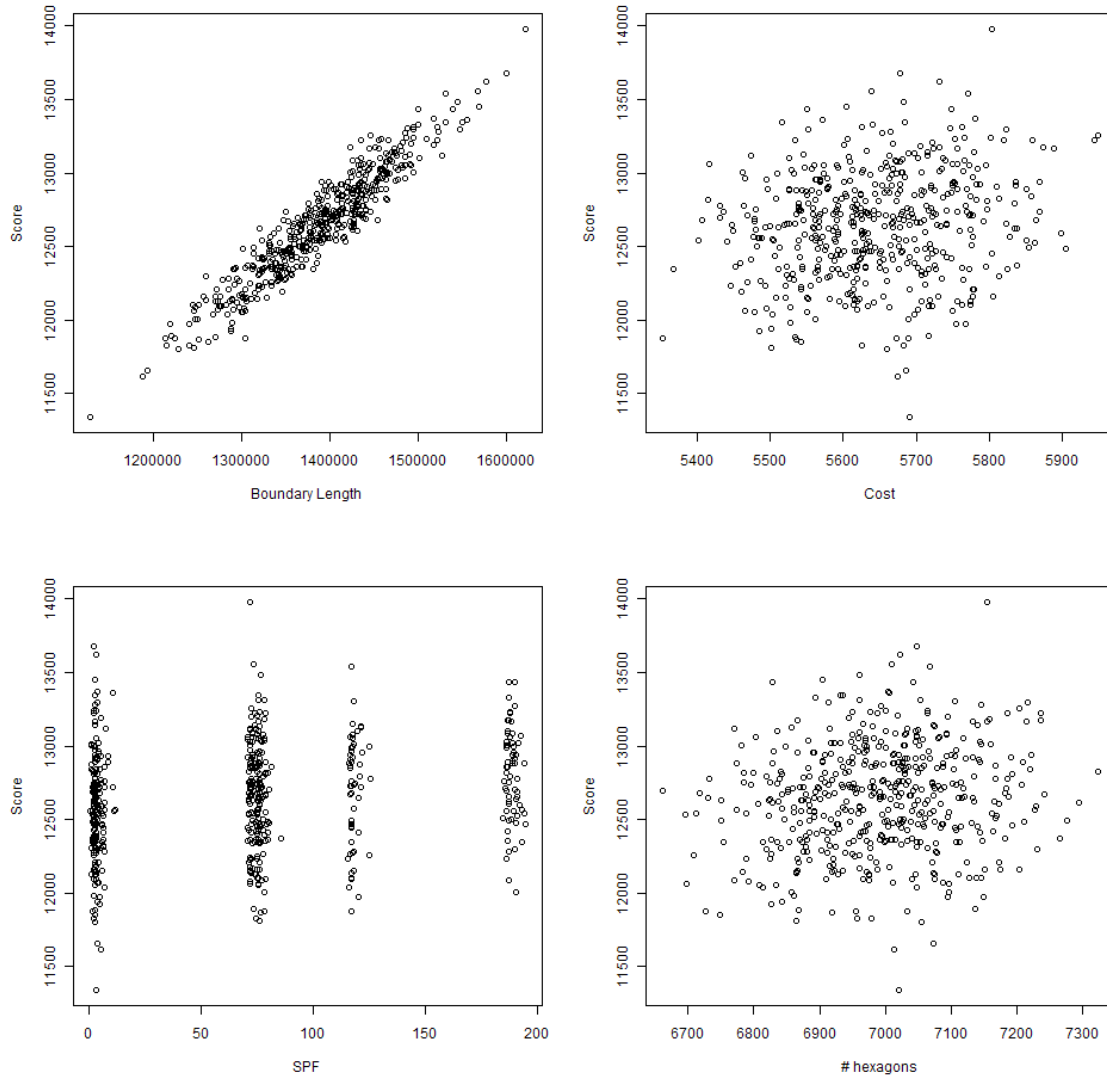
Figure 9: BLM 0.005
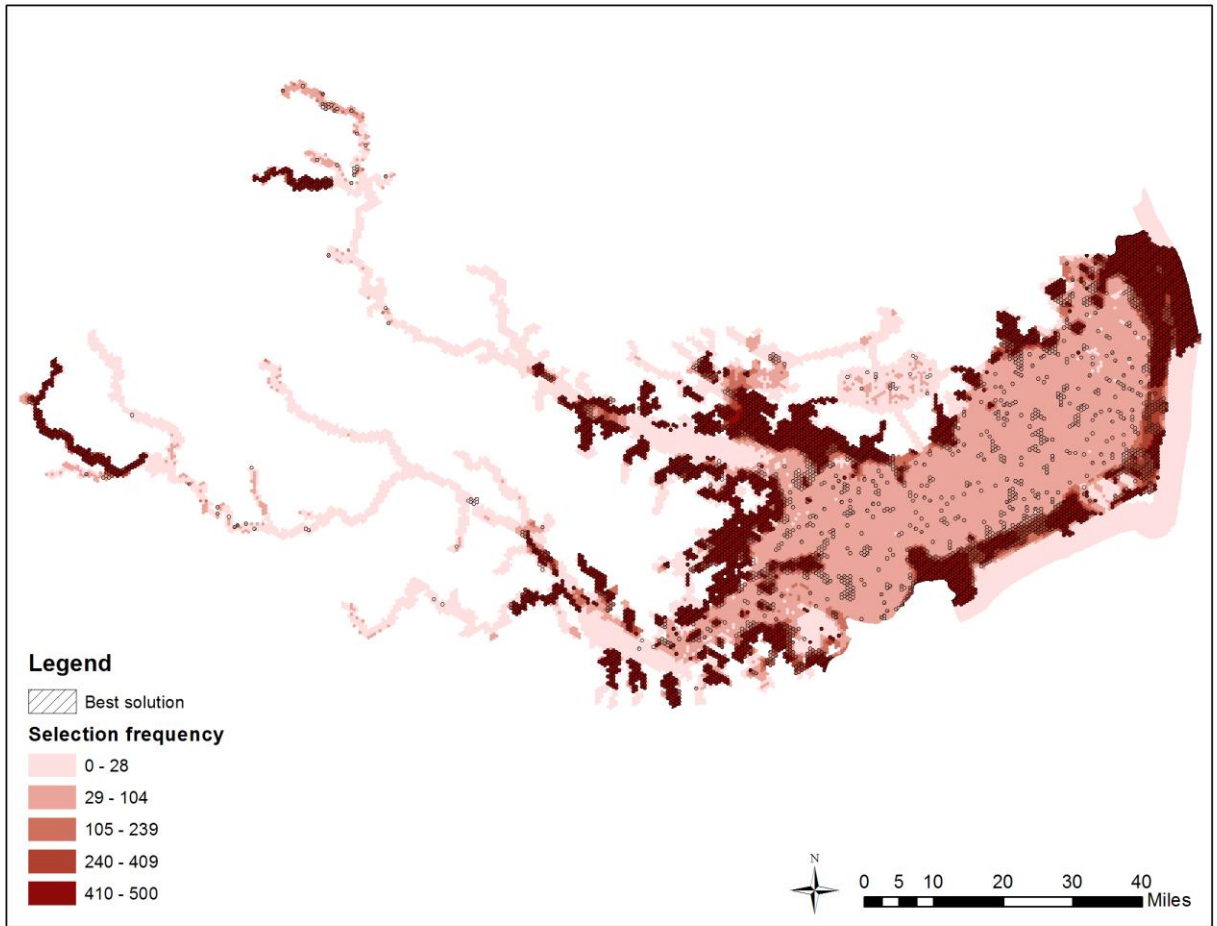
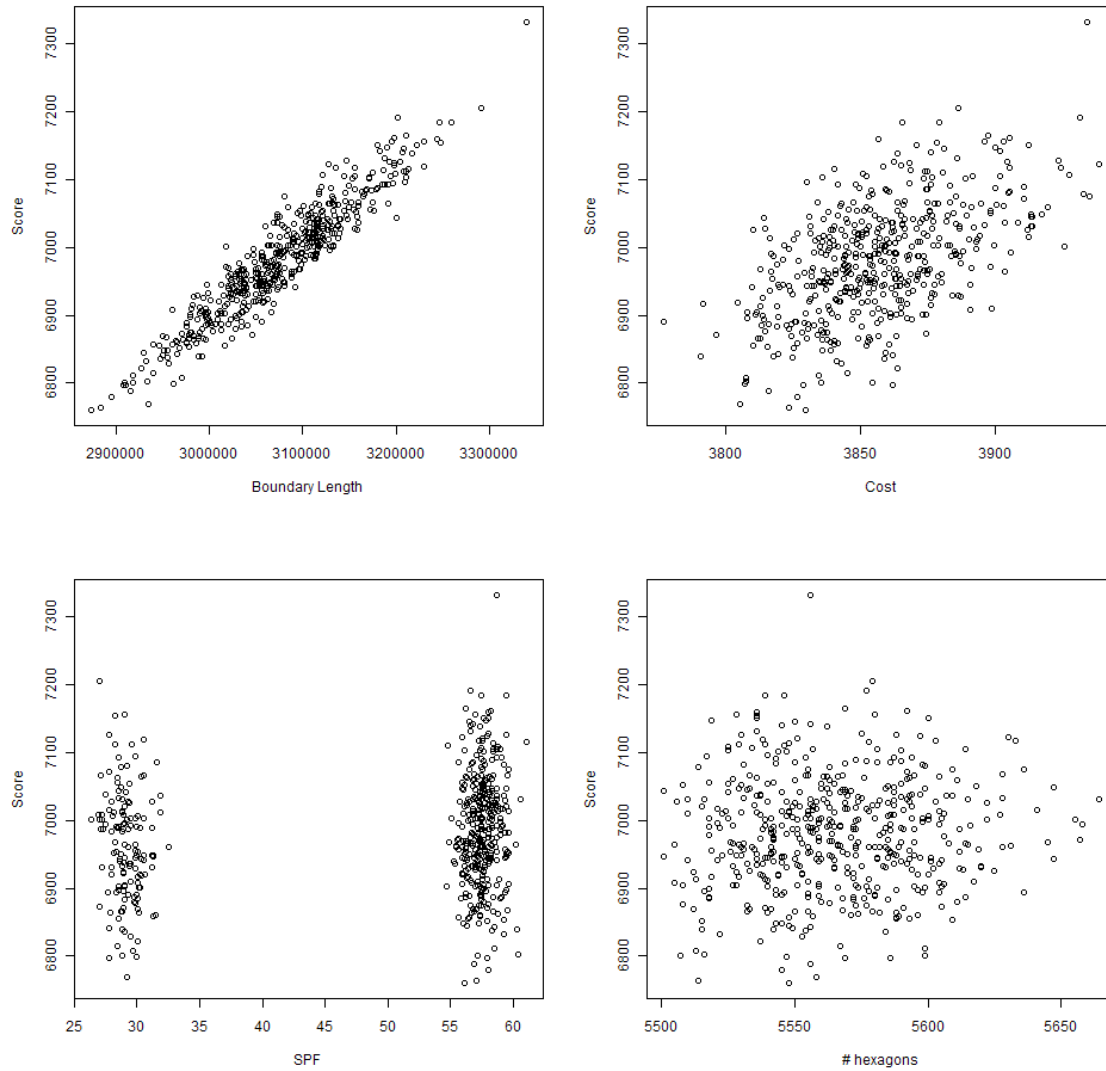**Figure 10: BLM 0.001**

Figure 11: BLM 0.001

Reference
Ardron, J.A., Possingham, H.P., Klein, C.J. (eds) 2008. Marxan Good Practices Handbook. External review version; 17 May 2008. Pacific Marine Analysis and Research Association, Vancouver, BC, Canada. 155 pages. www.pacmara.org

APPENDIX F: PUBLIC MEETING COMMENTS

A public meeting was held on October 11, 2011. Eight members of the public attended, in additional to agency staff. The memo below summarizes the comments. Following the meeting, written comments were received from Mazie Smith, Hyde County manager. A Hyde County representative also spoke at the MFC meeting reiterating their written comments that they were concerned with any potential regulations that may result later due to SHA designations, and the effect of regulations on their economy.   The SHA Advisory Committee discussed the comments and had no objections to adjusting the SHA boundary in the vicinity of the Trent River, where it included urbanized areas of New Bern, but felt the areas selected in Hyde County and elsewhere were appropriate. The meeting memo below summarizes the public comments.

MEMORANDUM

TO: N.C. Marine Fisheries Commission (MFC)
                Strategic Habitat Area Region 2 Advisory Committee
                Louis Daniel

FROM: Anne Deaton

DATE: November 1, 2012

SUBJECT: Public Meeting – input on Strategic Habitat Area (SHA) Region 2

A public meeting was held on Tuesday, October 11, 2011 at 6:00 pm at the Washington Regional Office located at 943 Washington Square Mall. The following staff attended:

Staff: Anne Deaton, Kevin Hart, Christine Jensen, Jimmy Johnson

Eight people, in addition to staff, attended the meeting.

The meeting began with Anne Deaton reviewing the process/method used and showed the areas selected for Strategic Habitat Area (SHA) nomination. She summarized what habitats and alterations were considered in the assessment and the prominent features within the selected SHAs. Division of Marine Fisheries (DMF) staff emphasized that the Strategic Habitat Area assessment was an ecological evaluation that was not considering management needs at this point, but was simply identifying a network of priority high quality habitat areas - the best of the best habitats. The evaluation was conducted following a process established by the DMF and an advisory committee. A separate advisory committee, with local research knowledge was used to review the methods, input data, and results of this assessment. Field groundtruthing will be conducted following this to confirm condition within the SHAs and consider if any conservation measures are needed. Once North Carolina's entire coast has been evaluated (approximately half remains to be done), management measures may be considered but will involve extensive public stakeholder involvement. The driving reason for conducting SHA analyses is because scientific literature indicates that protecting a network of priority habitat areas is an effective means of enhancing sustainable fisheries.

The habitats in the SHAs along the Outer Banks contain large beds of seagrass, intertidal flats, oyster beds, and wetlands. The areas on the mainland consist primarily of embayments identified designated as Primary Nursery Areas, and also containing some oyster beds, wetlands, shallow soft bottom, and some low elevation uplands. Some areas were also designated as Anadromous Fish Spawning Area and provide a connection to Lake Mattamuskeet. Some subtidal shell bottom at the mouth of the rivers were included.   Selections on the rivers were concentrated in the lower estuarine waters and in the headwaters. Some mid river tributaries on the rivers due to habitats and known anadromous fish use.

It was pointed out that many of the areas selected were within an existing federal or state property and already protected from land use activities, or contained fisheries designations, such as Primary Nursery Areas, where rules are already in place to provide protection from bottom disturbance.   There was discussion on what could be done to benefit such areas. It was pointed out that some may only need the existing protections to remain in place. Water quality affecting habitat condition was mentioned as the primary concern for the region.

Some of the comments were positive, while some had concern. Some of the points raised:
- There was a concern that such a large area of Hyde County was selected and that it might result in fishing restrictions. Did not like being a "target" and did not want further fishing restrictions.
- Others mentioned that the selection of a large amount of area in Hyde County was a recognition of the significance and uniqueness of the area.
- One person said he was glad that a lot of wetland areas in Hyde County seemed to have been included because they are so important to many resources.
- The SHA areas should be used to protect and maintain these high quality habitats, to sustain fisheries, and not restrict fisheries.
- The SHAs represent aquatic assets that the area needs to support the fishing and tourism industries.
- SHA areas along the northeast side of Trent River include some developed areas and should consider removing.
- Low elevation uplands adjacent to wetlands should be considered for protection to allow migration of wetlands as sea level rises.

The SHA Advisory Committee will consider all the comments and make adjustments if found necessary before finalizing.
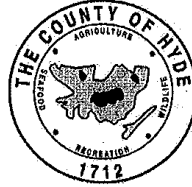
Board of Commissioners
Sharon Spencer, Chair
Anson Byrd, Vice-chair
Darlene Styron
Barry Swindell
Dick Tunnell

COUNTY OF HYDE

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SWAN QUARTER, NORTH CAROLINA 27885
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Mazie Swindell Smith
County Manager

Fred Holscher
County Attorney

October, 24 2011

W. Robert Bizzell
Chairman, Marine Fisheries Commission
N.C. Division of Marine Fisheries
3441 Arendell Street
Morehead City, NC 28557

Dear Mr. Bizzell,

Based on recommendations from staffers in the Hyde County Office of Economic Development and Planning, the Hyde County Board of Commissioners passed a resolution on October 17th formally opposing regulatory action in the Strategic Habitat Area (SHA) waters of the Pamlico Sound and the Atlantic Ocean. A copy of the resolution is attached. The Commissioners request that this resolution be entered into the record of the November 2011 Marine Fisheries Commission meeting.

The commissioners agreed with the scientific findings in the proposed SHA area, and acknowledged the waters are relatively free of pollution and that fish stocks are exceptional. The findings seem to indicate that no regulatory action is needed. The commissioners are concerned however that the SHA designation will lead to additional regulations for fishermen, resulting in significant loss of income and jobs for the county. Fishing, both commercial and recreational, is part of our heritage, our culture and our very way of life, and fishing-related industries account for a large portion of our workforce, along with farming and agriculture. It is the belief of the Board that any additional regulatory action -- over and above what our citizens already must follow -- would cause severe, negative consequences on both the fishing and farming industries.

Because of the potential impact to our local economy, any consideration to changes in management of our waters should come only after citizen input. The commissioners want to be active participants in the decision-making process for any regulations which impact our citizens. We thank you in advance for ensuring that we are given that opportunity.

Respectfully,

Mazie Smith, Hyde County Manager

Cc: Senator Stan White
Representative Tim Spear

"On the journey toward progress down the road less traveled..."

A RESOLUTION OF THE HYDE COUNTY BOARD OF COMMISSIONERS OPPOSING REGULATORY ACTION IN THE STRATEGIC HABITAT AREA OF THE PAMLICO SOUND AND ATLANTIC OCEAN

WHEREAS, the N.C. Division of Marine Fisheries has proposed a Strategic Habitat Area (SHA) in waters of the Pamlico Sound and Atlantic Ocean with much of the designated area surrounding mainland Hyde and Ocracoke; and

WHEREAS, the County of Hyde has a 300-year history of commercial fishing in proposed SHA waters with targeted species of shrimp, oysters, crabs, southern flounder, red drum, speckled trout and androgynous fish; and

WHEREAS, the County of Hyde is one of the most economically distressed in the state and relies heavily on income from fishing and further regulations would be detrimental to the economy and heritage of the county; and

WHEREAS, DMF studies show waters surrounding the county are relatively free of pollution and water quality alteration factors, and therefore should warrant no further regulatory action towards fishermen;

WHEREAS, a large quantity of land in Hyde County is already federally protected and access to natural resources should not be further limited; and

NOW THEREFORE BE IT RESOLVED, BY THE <u>BOARD OF COMMISSIONERS</u> OF THE <u>COUNTY OF HYDE</u>:

That the County of Hyde opposes further fisheries regulations in the proposed Strategic Habitat Area waters of the Pamlico Sound. The county supports DMF findings that the proposed SHA areas are ideal habitats for marine life and fish stocks. However, the county does not want SHA designation to further restrict access to marine resources, as commercial and recreational fishing are industries of significant economic importance in Hyde County.

Adopted this date OCTOBER 17, 2011 at THE GOVERNMENT CENTER, SWAN QUARTER, North Carolina.
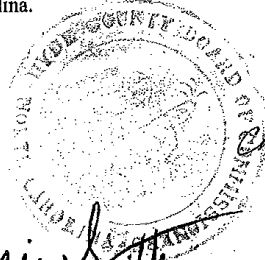
_____
(Signature of Chief Executive Officer)

_____
(Title)

ATTEST:

_____
Clerk   (Seal)