Strategic Habitat Area Nominations for Region 3:

The White Oak River Basin in North Carolina

FINAL REPORT

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By

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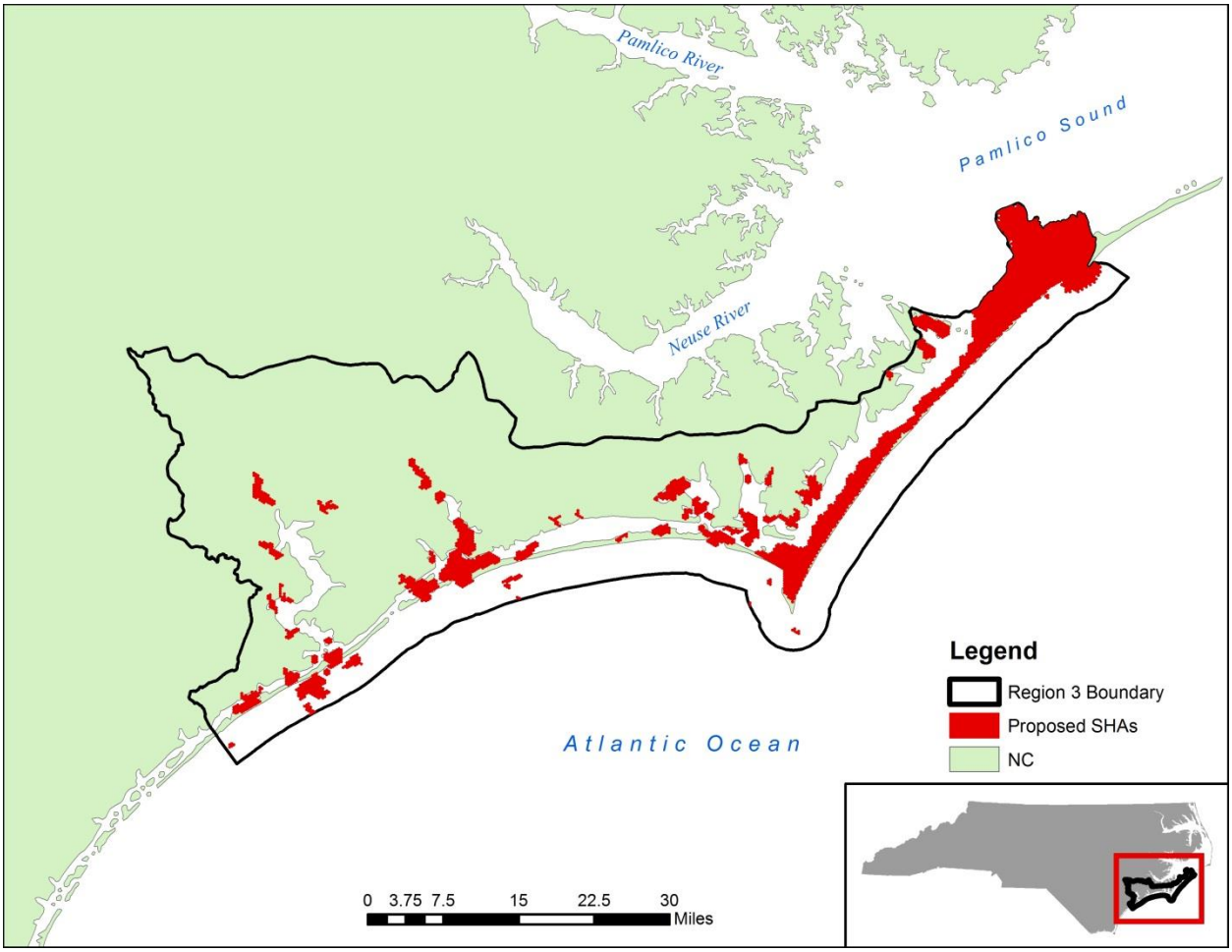
GLOSSARY OF ACRONYMS

NAME	Abbreviation
CHPP	North Carolina Coastal Habitat Protection Plan
DCM	North Carolina Division of Coastal Management
DMF	North Carolina Division of Marine Fisheries
DOT	North Carolina Department of Transportation
DWQ	North Carolina Division of Water Quality
DWR	North Carolina Division of Water Resources
GIS	Geographic Information System
HU	Hydrologic unit
MFC	North Carolina Marine Fisheries Commission
NHD	National Hydrologic Dataset
NOAA	National Oceanographic and Atmospheric Administration
NRT	Natural resource targets
NWI	National Wetlands Inventory
SAV	Submerged aquatic vegetation
SGA	Shellfish Growing Area
SHA	Strategic Habitat Area
SS&RWQ	North Carolina Division of Marine Fisheries – Shellfish Sanitation and Recreational Water Quality section
USACE	United States Army Corps of Engineers
WRC	North Carolina Wildlife Resources Commission
WTP	Water treatment plant
WWTP	Waste water treatment plant

EXECUTIVE SUMMARY

Strategic Habitat Areas (SHAs) represent priority locations for protection or restoration due to their exceptional ecological functions or areas that are particularly at risk due to imminent threats to their ability to support coastal fisheries. Identification and designation of SHAs is a main goal of the North Carolina Coastal Habitat Protection Plan. 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. Division of Marine Fisheries staff and the advisory committee specified representation levels for multiple unique habitat types. There are also several types of alteration factors that are represented geospatially (i.e., hydrologic alterations, water quality degradation, and physical disturbances). The site selection program Marxan was used to select areas that met representation levels while limiting the selection of highly altered sites. The scientific advisory committee modified the computer results based on their expert knowledge and experience. The resulting SHA nominations encompass 19% of the Region 3 focus area (i.e., riparian targets within 500 m of the shoreline, open waters and the Atlantic Ocean out to 3 nmi) (Map 1). There were 48 discrete SHA units selected within Region 3. A large area of Core Sound was selected due to its biodiversity and high quality of habitats and fishery species. Many of the SHAs overlap with lands that are already managed for conservation. The SHAs were corroborated with biological data, ecological designations, and specific knowledge of the area. The SHA nominations will be incorporated into future conservation and restoration planning efforts.



Map 1. Region 3 SHA Nominations.

INTRODUCTION

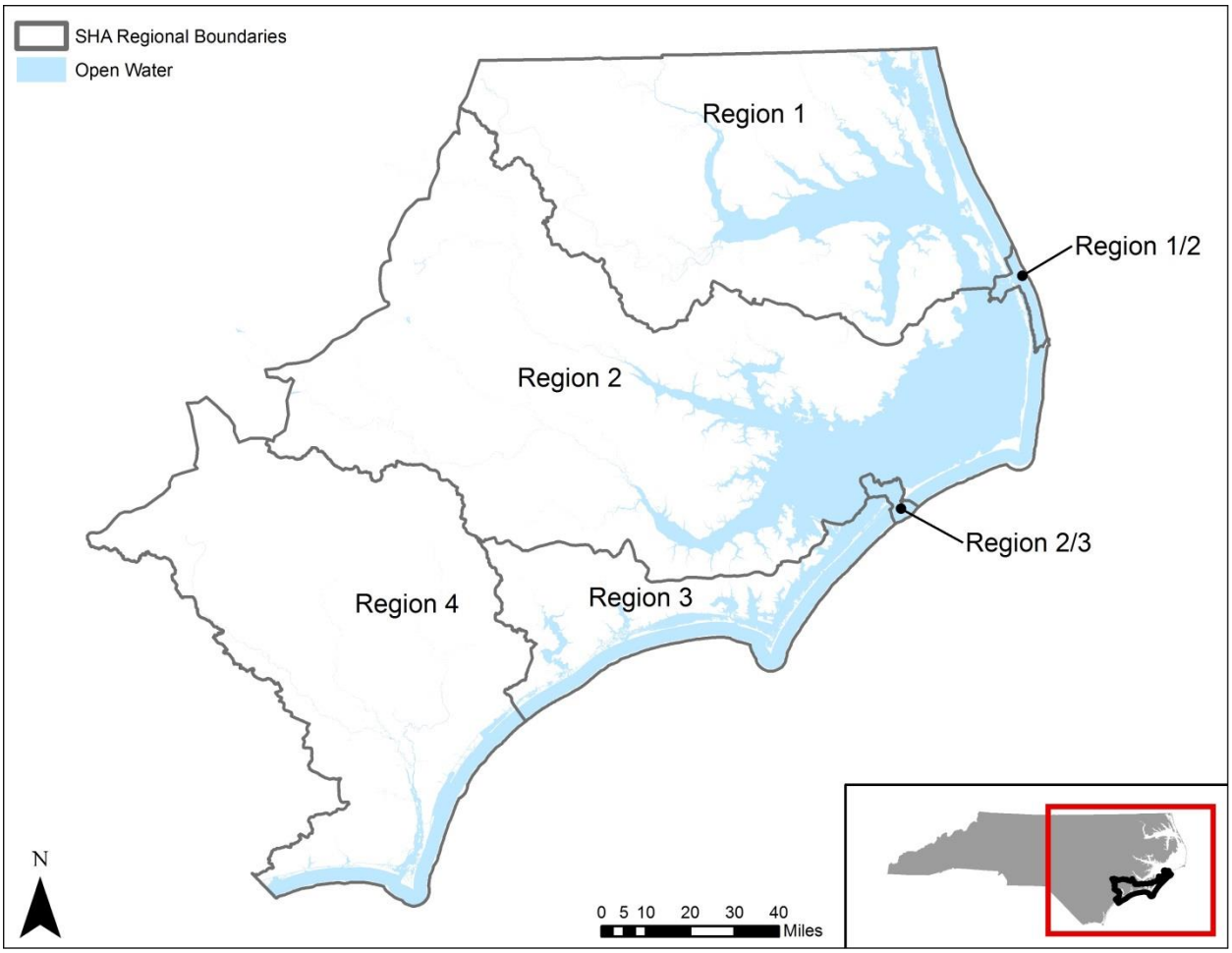
The identification and designation of Strategic Habitat Areas (SHAs) for marine and coastal fishery species is a critical component in the implementation of North Carolina's approved Coastal Habitat Protection Plan (CHPP). Strategic Habitat Areas were defined in the CHPP as, "specific locations of individual 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 guidance document entitled, "Process for Identification of Strategic Habitat Areas" (Deaton et al. 2006) that was approved by the Marine Fisheries Commission (MFC).

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

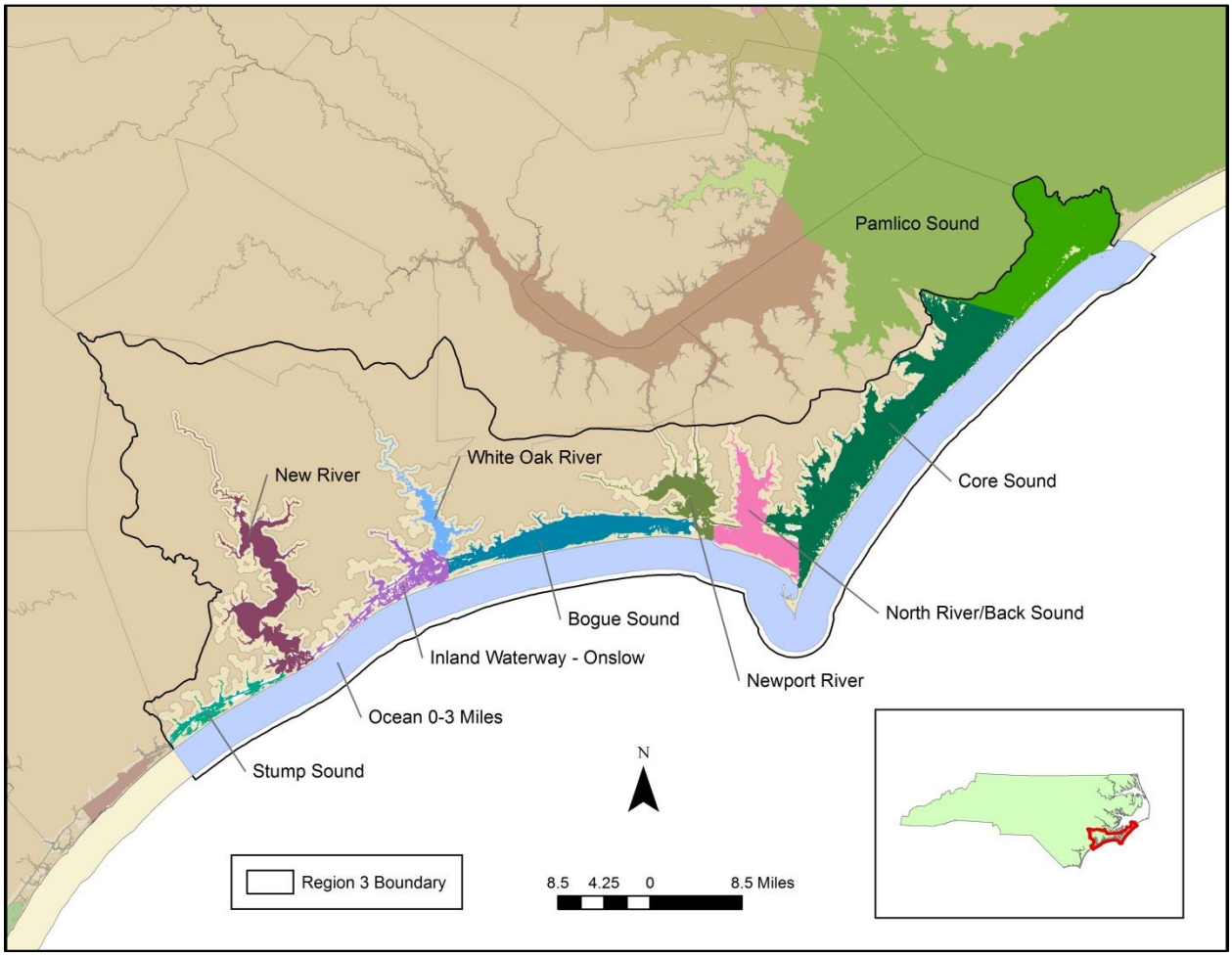
The identification of SHAs addresses the continuing degradation and loss of important habitats referenced in the CHPPs (Deaton et al. 2010; Street et al. 2005). Current rules and policies of the resource management agencies fail to adequately address the individually small but cumulatively large alterations of fish habitat for development and associated human activities (Deaton et al. 2010; Street et al. 2005). 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 1) natural resource targets, 2) alteration factors, 3) the spatial landscape, and 4) fish distribution and movement. Averting threshold levels of cumulative alteration to SHAs could be accomplished with both regulatory and non-regulatory tools, although the focus will be on non-regulatory tools.

Four regional analyses are being done to identify SHAs in coastal waters. Region 1 (Albemarle Sound System) and Region 2 (Pamlico Sound system) were completed in 2009 and 2011, respectively (Map 2). SHAs in these regions are already being used by conservation groups to a limited extent. Once all four analyses are complete, staff will focus on developing site-specific measures to protect and enhance SHAs.

Geographic Scope of Region 3



Map 2. Regional boundaries for Strategic Habitat Area nominations.



Map 3. Major water bodies in Region 3.

Region 3 is the smallest of the four SHA regions (Map 2) and includes waters in Carteret and Onslow counties, as well as a small amount of Jones and Craven counties (Map 3). Unlike the other three regions, the entire watershed is contained within the coastal plain and within a single river basin (White Oak River Basin), lacks extensive riverine systems, and consists primarily of estuarine waters and small to moderate sized sounds. Sounds within Region 3 include Stump, Back, Bogue, and Core sounds (Map 3). Major rivers include the New, White Oak, Newport, and North rivers (Map 3). Water flows out of these estuarine rivers and sounds to the ocean through several inlets. The northernmost inlet, Ocracoke Inlet, overlaps with Region 2 where SHAs were already nominated (Map 2); therefore, this area is already included in the SHA network since it was chosen in region 2. The other inlets, Drum, Barden, Beaufort, Bogue, Bear, Browns, and New River inlets separate the islands of Core Banks, Shackleford Island, Bogue Banks, Bear Island, Brown's Island, Onslow Beach, and North Topsail Island and allow critical ingress and egress of fish. Lunar tides are more dominant than wind tides in Region 3.

All six habitat types described in the CHPP (Deaton et al. 2010) are present within the region. Compared to the areas north of the White Oak River Basin, water bodies in Region 3 are generally smaller and more saline, and intertidal oyster reefs and ocean hard bottom are more abundant. Submerged Aquatic Vegetation (SAV), wetland marsh, and forest are extensive. The majority of the inside waters in this region are classified by the Division of Water Resources (DWR) as shellfish waters (SA waters). There is an abundance of designated Primary Nursery Areas due to the numerous shallow tidal creeks and excellent estuarine nursery conditions. The abundance of healthy and diverse habitats in the White Oak

River Basin supports numerous commercial and recreational fisheries.

Land Use

Land use in the White Oak River Basin is predominantly forest and federal land (i.e., developed and undeveloped military property, national forest, and national seashore), with lesser acreage of agriculture and residential development (DWQ 2007). Development on the mainland side of Region 3 is concentrated in the towns of Morehead City, Beaufort, Swansboro, Newport, Jacksonville, as well as Marine Corps Base Camp Lejeune. Of the barrier islands, only Bogue Banks and Topsail Island are developed, with the majority of housing supporting seasonal tourism. The other barrier islands are under federal or state ownership. Population in the White Oak River Basin is estimated to be 354,511 by 2020. The New River watershed (i.e., Jacksonville and Camp Lejeune) is the most populated and densely developed. The Down East area of Carteret County, while the least developed area, contains large acreage of agricultural land. The largest areas of undeveloped land in the region are at Cape Lookout National Seashore, Croatan National Forest, and Marine Corps Base Camp Lejeune. In the past two decades, population in the region's communities increased significantly. From 1990 to 2010, Onslow County population increased 22%, and Carteret County population increased 23%. Overall, urban development has increased 65% since 1982 (DWQ 2007). As development has increased inland, forestry and agriculture have declined.

The rapid increase in urban development is the greatest threat to fish habitat and resources in this region. Increasing stormwater runoff and loading from point sources can lead to increased bacteria, nutrient, sediment and toxin inputs. The DMF Management Review Team noted increasing shellfish harvest closures as a priority threat throughout the region. Algal blooms and low dissolved oxygen were a concern in New River and Bogue Sound. Degraded nursery conditions due to toxin and nutrient contamination, sedimentation, and altered flow and salinity was also considered a concern overall.

Identification of Priority Species

The White Oak River Basin is a focal point for the oyster, clam, bay scallop, blue crab, and shrimp fisheries and is an important area for southern flounder, red drum, spotted seatrout, weakfish, spot and an important nursery area for gag and black sea bass. All of these species were considered priority species for Region 3 by the DMF Management Review Team (Table 1). In general, these priority species tend to be most abundant in shallow water, and have strong associations with SAV, shell bottom, and wetlands.

The 2010 CHPP states that "The areas that contribute most to the integrity of the system are a category of habitat termed Strategic Habitat Area" (Deaton et al. 2010). In a general sense, the abundance and diversity of habitat such as shallow nursery areas, SAV, and oyster beds is what sustains productivity in Region 3. The Region 3 SHA assessment focused on identifying habitat areas that provide critical functions to various life stages of priority species and are minimally degraded.

Table 1. Priority fishery species and commercial landings from Region 3 waters, in 2003 and 2013.

	Landings (pounds)	
Priority Species	**2003**	**2013**
Blue crab	2,485,367	937,300
Shrimp	1,548,377	865,268
Hard clam	384,479	306,642
Southern flounder	448,393	295,959
Spot	591,367	243,467
Oyster	112,153	131,772
Spotted seatrout	54,842	64,729
Red drum	14,266	54,310
Weakfish	141,587	21,615
Bay scallop	13,969	963

METHODOLOGY

A guidance document was developed to direct the methods for identifying SHAs (Deaton et al. 2006). The SHA identification process consists of three main phases, each of which requires input from a regional expert panel. The first phase in the SHA process is to identify priority species and habitats, and build a GIS database of existing biological and anthropogenic use data for Region 3. The DMF Management Review Team selected priority species for the region based on their importance to both the recreational and commercial fishing industries in the region. Once data is assembled by DMF staff, the regional expert panel for Region 3 reviewed the data to ensure that they have sufficient spatial coverage and are current enough to be included in the SHA selection process. Then the panel examined the priority fish species for the region and suggested the amounts of each biological feature that the final SHA network should include. The second phase of the process was to run the site selection software Marxan (Ball et al. 2009) to determine an initial configuration of SHA networks. Once the Marxan modeling was complete, the third phase consisted of an expert committee reviewing the Marxan selections and using corroborating information and their own ecological knowledge to modify the boundaries of the SHA network and derive a final network of SHA nominations.

Natural Resource Targets

In this analysis, "Natural resource targets (NRTs)" are defined as the habitats that represent essential or unique components of the fisheries ecosystem. Natural resource targets vary by region and should be chosen to differentiate between habitats that are used differently by fish species. To do this, priority species were grouped into shellfish, winter spawning estuarine fish, summer spawning estuarine fish, and reef fish based on common life history strategies (Table 2). Each NRT was evaluated based on its value to these species' groups. Once identified, the use of NRT by each group of priority species was used to set representation levels (the amount of a habitat to be included in the SHA network). In addition to the importance to priority species, the ability of the NRT to improve water quality was also considered when setting representation levels. After an initial value was set, representation levels were adjusted 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 NRTs and the chosen representation levels are listed in Table 2.

Table 2. Natural resource targets (NRTs) and representation levels used in the analysis and the importance of each NRT to priority species in Region 3.

Habitat type	Natural resource target	Total acres/mi	Rep level (%)	Importance to priority species				
				Shellfish	Winter spawning est. fish	Summer spawning est. fish	Reef fish	Contribution to water quality
				oysters, hard clams, bay scallops	southern flounder, spot, shrimp	blue crab, spotted seatrout, red drum, weakfish, shrimp	gag, black sea bass	-
Polygon habitat types (all area values are in acres)								
Hard bottom	Hard bottom*	3,839	-				X	
SAV	High salinity SAV	32,265	60	X	X	X	X	X
	Low salinity SAV	33	90		X	X		X
Shell bottom	Intertidal shell bottom	1,357	50	X	X	X	X	X
	Subtidal shell bottom	2,370	60	X	X	X	X	X
SAV & shell bottom	SAV & shell bottom	349	60	X	X	X	X	X
Creeks & Rivers	Riverine soft bottom (0-3ft)	5	30	X	X	X		
	Riverine soft bottom (3-6ft)	4	0		X	X		
	Riverine soft bottom (ND)	331	0		X	X		
Shallow soft bottom	Palustrine soft bottom (0-3ft)	12	20		X	X		
	Palustrine soft bottom (ND)	215	0		X	X		
	Estuarine (0-3ft)	76,823	30	X	X	X		
	Estuarine (3-6ft)	42,421	20	X	X	X		
	Estuarine (ND)	10,450	10	X	X	X		
	Marine (0-3ft)*	4,611	-		X	X		
	Marine (3-6ft)*	4,406	-		X	X		
Deep soft bottom	Estuarine (>6ft)	44,004	0	X	X			
	Marine (>6ft)*	242,402	-		X			

Habitat type	Natural resource target	Total acres/mi	Rep level (%)	Importance to priority species				
				Shellfish	Winter spawning est. fish	Summer spawning est. fish	Reef fish	Contribution to water quality
				oysters, hard clams, bay scallops	southern flounder, spot, shrimp	blue crab, spotted seatrout, red drum, weakfish, shrimp	gag, black sea bass	-
Wetland	Emergent	39,033	10		X	X		X
	Forested	23,181	10		X	X		X
	Shrub/scrub	10,665	0					X
Low-elevation upland	Low-elevation upland	7,733	10					X
TOTAL AREA w/o hard bottom & ocean		**546,511**						
TOTAL AREA w/ hard bottom & ocean		**693,706**						

Line habitat types (all distance values are in miles)								
Streams	Streams (low elevation)	687	10		X	X		
Low-elevation upland	Non-wetland shoreline	423	10		X	X		
Wetland shoreline	Wetland shoreline	2,274	40		X	X		X
TOTAL DISTANCE		**3,384**						

*Not included in Marxan calculations

Hard bottom

Locations of hard bottom in the ocean are not well documented, and only few datasets exist that give specific locations and information about hard bottom habitats. For the Region 3 analysis we combined data from several different data sets to create a mosaic of hard bottom habitat. The most extensive survey was based on the Southeast Area Monitoring and Assessment Program's reef-dependent fish collections from the 1990s (SEAMAP 2001) and Moser and Taylor (1995). In addition the list of wrecks and obstructions was obtained from the Automated Wrecks and Obstructions Information System database (http://www.nauticalcharts.noaa.gov/hsd/wrecks_and_obstructions.html). A Natural Heritage Area of hard bottom off of New River was also included. Because of its importance to priority species such as gag and black sea bass and the lack of mapping data documenting hard bottom habitat, all known locations of hard bottom material were selected in the proposed SHA network for Region 3 excluding DMF artificial reefs that were created for the purpose of recreational fishing.

Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation beds were mapped using aerial photography interpretation and transect data interpolation. Source data ranged in date of acquisition from the late 1980s to the very recent (Ferguson and Wood 1994, DMF Estuarine Benthic Habitat Mapping Program 1988-March 2012, unpublished data; APNEP 2007-2010). 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 communication). Because of this, the extent of SAV habitat is likely somewhat underrepresented by the mapping data, particularly in the rivers.

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. There was very little low-salinity SAV in Region 3.

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 (60%). 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 90%.

Shell bottom

Shell bottom habitat in Region 3 was based on interpolated transect data collected by the DMF Estuarine Benthic Habitat Mapping Program. The source data ranges from 1988 to 2013, depending on the geographic area. The shell bottom target is defined as areas with at least 30% coverage of shell material (typically oysters) in water generally less than 12 feet deep. Shell bottom is subdivided into intertidal and subtidal by the Estuarine Benthic Habitat Program.

Other sources of data were incorporated into the shell bottom target, including included cultch planting sites (DMF unpublished data, 1981-2013). Line features of cultch planting locations were converted to polygons where the width of the polygon was proportional to the number of bushels deployed. Cultch

planting data was classified as either intertidal or subtidal based on depth recorded at the time of deployment. Representation levels were set at 50% for intertidal shell bottom and 60% for subtidal shell bottom because they are regionally important as a fishery resource, serve as fish habitat, and are important for maintaining water quality.

Low-Elevation Uplands

Low elevation uplands were included because they are potential sites for marsh migration with as inundation occurs (Deaton et al. 2010). A 2008 3 m digital elevation model with a vertical accuracy of 25 centimeters (http://ned.usgs.gov/) was used to select areas less than two feet above mean sea level and having a patch size greater than 25 m^2. Non-wetland shorelines were also included in this category of uplands. The non-wetland shoreline was derived from North Carolina Division of Coastal Management's estuarine shoreline data (http://portal.ncdenr.org/web/cm/download-spatial-data-maps-oceanfront). A 15-m landward buffer was applied to the shoreline and the resulting data was combined with the uplands derived from the digital elevation model. Only low elevation uplands adjacent to other natural resource targets were retained; all others were eliminated from the dataset.

Wetlands

Wetland targets were extracted from the National Wetland Inventory (NWI) where wetlands are classified according to Cowardin et al. (1979). Wetlands of the following types are included in the Region 3 analysis were estuarine intertidal emergent, shrub/scrub, and forested wetlands and palustrine emergent, shrub/scrub, and forested wetlands. Only contiguous wetlands within 90 m of a stream or shoreline were included as a target for assessment.

Wetland edge

This target consists of the linear wetland edge as designated in the North Carolina Division of Coastal Management's estuarine shoreline data layer. The wetland edge target does not differentiate between the marsh and forested edges. The inclusion of wetland edge, in addition to riparian/interior wetlands, was intended to capture the important linear ecotone within aquatic systems. Wetland shorelines are important habitat for juveniles of some priority species.

In Region 2, the linear wetland edge features were buffered and converted to polygon features. Unlike the Region 2 analysis, the Region 3 analysis retained the linear wetland edge feature during the alteration weighting calculation. The linear features were retained with the intention of maintaining the integrity of the linear dataset. Because the natural resource target features were linear as were many of the alterations affecting these features, converting the features to polygons created the potential to falsely inflate the alteration or impact within an assessment hexagon.

Non-wetland shoreline

This target consists of the linear non-wetland edge as designated in the North Carolina Division of Coastal Management's estuarine shoreline data layer. The inclusion of non-wetland edge, in addition to the low elevation uplands, was meant to capture the ecotone or transition zone between ecological systems, a potentially important habitat for priority species.

In Region 2, the linear non-wetland edge features were buffered and converted to polygon features. Unlike the Region 2 analysis, the Region 3 analysis retained the linear non-wetland shoreline during the alteration weighting calculations. The linear features were retained with the intention of maintaining the integrity of the linear dataset. Because the natural resource target features were linear as were many of the alterations affecting these features, converting the features to polygons created the

potential to falsely inflate the overall alteration or impact within an assessment hexagon.

Streams

Small creeks and streams were represented using the National Hydrography Dataset's high resolution data (1:24,000-scale). This dataset represents a connected network of stream channels. The streams were clipped out of the open water features to leave a continuum from linear to polygon water features. The artificial connectors, an artifact needed to maintain the dataset's continuous linear network between features, were removed from the dataset because they did not represent stream habitat (these were not removed in the Region 2 analysis).

There are three basic linear water features (upper, middle, and lower) were created based on elevation (1 arc-second National Elevation Dataset). Stream order was not used because it was not readily available and much of Region 3. Three elevation zones were set based on natural breaks occurring from sea level up to the fall line of riverine channels. 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.

Soft bottom

Soft bottom or water column habitat was designated as any area without submerged aquatic vegetation, shell bottom, or other structured habitat. This soft bottom habitat was derived using the North Carolina Division of Coastal Management's estuarine shoreline layer, the National Oceanic and Atmospheric Administration's bathymetry contour dataset, and the U.S. Fish and Wildlife's National Wetlands Inventory (NWI) dataset. The DCM estuarine shoreline data (McVerry 2012) was used as the base or boundary for the soft bottom natural resource target because it was recently digitized using high quality aerial imagery. All other structured features were removed from this base layer; this includes submerged aquatic vegetation, shell bottom, and hard bottom. The remaining features were considered soft bottom features.

The soft bottom features were further classified by depth and system. The depth categories included 0-3ft, 3-6ft, and no depth. These distinctions are important because they correspond to major differences in ecological function (i.e., shallow water nurseries). Depth was derived from NOAA's bathymetric dataset (http://nauticalcharts.noaa.gov). The "no depth" category was assigned to channel-like hydrographic features adjoining more open waters, or where the bathymetric charts indicated no data. The soft bottom habitats are also classified into system type using the NWI's wetland polygon dataset and classification system (Cowardin et al. 1979). Any soft bottom habitat that did not have a hydrological connection to riverine or estuarine systems by linear water features was removed from the dataset by applying a 30 meter buffer to determine connectedness of water bodies (i.e., lakes and ponds) to adjacent water features. Soft bottom habitats are classified into riverine, estuarine, palustrine, and marine systems.

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

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

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, bottlenose dolphins, 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 3. 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 3, sea turtles are thought to be most abundant in Core Sound, particularly near Cape Lookout but can be found throughout the sounds and lower rivers. Their habitat will be targeted indirectly through deep soft bottom.

Alteration Factors

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

Natural Resource Targets -> Alteration Factors

The natural resource targets for Region 3 were grouped into general habitat categories for the purpose of applying alteration factor ratings. For example, wetland types are affected similarly by ditching and drainage; therefore they form one habitat type for alteration calculations. However, there were linear and polygon wetland and shoreline features. In Region 2, these linear features were converted to narrow polygon features. This conversion was also done for linear stream features. In Region 3, a decision was made to retain the linear features of the natural resource targets. The SHA Advisory Committee decided that the wetland edge linear features themselves were an important structural component of a habitat. The alteration calculations were applied to both polygon and linear features. In order to apply the equations presented in 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 in Table 2 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
- Soft bottom, deep – All categories of estuarine and marine soft bottom >6 feet deep. This category represents soft bottom under standing water conditions.
- Soft bottom, shallow – All categories of estuarine and marine soft bottom <6 feet deep. This category represents soft bottom under standing water conditions.
- Uplands – 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.
- Wetland – 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.

- Streams – 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. Some of these may have been used during the corroboration phase. Their use was excluded for the following reasons:

- DWQ use support ratings were not used because we primarily needed aquatic life use support, which wasn't available in all locations.
- Stormwater outfall maps from DWQ and SS&RWQ were incomplete for the region; the DWQ data covers only municipalities and the SS&RWQ 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, previous advisory committees felt the alterations to aquatic habitat were minor relative to other threats, and the activity was difficult to represent spatially (Deaton et al. 2010; Uphoff 2008).
- Dredge material disposal on beaches has occurred in the region (Deaton et al. 2010), but was not included in the alteration factors, since it was episodic and less frequent than beaches with long term storm protection projects.

Table 3. Alteration factor weightings used in the Marxan analysis.

	Hydrology								Water Quality									Physical		
Habitat Groups	Culvert-obstructed areas	Impoundments	Bridge constrictions	Bulkheads	Rip rap	Dredged channels	Ditched/drained	Canals & boat basins	Major NPDES	Minor NPDES	Marinas	Animal operations	Mining discharge	Developed land use	Agricultural land use	Prohibited shellfish harvest*	Piers, docks, bridges	Trawling and dredging (perm open)	Trawling and dredging (temp open)	Mechanical clam harvest
Creeks & rivers	2	2	1	1	1	1	-	1	2	1	1	1	1	2	2	1	-	-	1	1
SAV	1	1	1	1	-	3	-	2	2	1	2	2	1	2	2	1	2	1	2	3
Shell bottom	1	-	1	-	-	3	-	1	1	1	2	1	1	2	1	1	-	1	2	3
Shell bottom & SAV	1	1	1	1	-	3	-	2	2	1	2	2	1	2	2	1	2	1	2	3
Deep soft bottom	-	1	-	-	-	1	-	1	2	1	1	1	1	1	1	1	-	-	1	1
Shallow soft bottom	-	1	-	2	1	2	-	1	2	1	2	1	1	1	1	1	-	1	2	1
Low-elevation uplands	1	1	-	2	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Wetland	1	2	1	1	0	1	2	1	-	-	1	1	1	1	1	-	1	-	-	-
Stream	2	2	-	1	1	1	2	-	3	2	-	2	1	2	2	-	-	-	-	-
Wetland edge	1	2	1	3	2	1	2	1	-	-	1	1	1	1	1	-	1	-	-	-

* Includes areas closed due to high bacteria levels but excludes areas closed exclusively due to marina and major PDES impacts.

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

1. *Overlap of habitat area and alteration footprint* – This was done for alteration features whose effect could be accurately represented by a discrete area. Altered areas for these features were represented as the area of the intersection between the habitats present and alteration. This was done for culverts-obstructed areas, impoundments, bridge constrictions, bulkheads, rip rap, dredged channels, ditched/drained wetlands, canals and boat basins, major NPDES, prohibited shellfish harvest, marinas, piers, docks, and bridges, Trawling, and mechanical clam harvest.
2. *Relative impact of the alteration factor to a hydrologic unit* – This was done for alteration factors that were theorized to have watershed-level impacts or if the data collection prevented a discrete area of impact from being delineated. To calculate this, the extent of an alteration factor (whether it be total area or the sum of point counts) is summed across a hydrologic unit and amount is scaled to the maximum value occurring in any hydrologic unit in the region. This includes minor NPDES, animal operations, mining discharge, developed land use, and agricultural land use.

Hydrological Alterations

Culvert-obstructed areas

This factor identifies the stream segments upstream of the first downstream culvert of both documented and possible culvert locations. The culvert data was assembled from various sources, including Collier and Odum (1989), Moser and Terra (1999), and Department of Transportation (2013 data, https://connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx). Possible culverts were located by creating a point where streams intersected roads with no bridge indicated on the DOT data. Culvert locations were visually verified if possible (if not obstructed by trees or other impediments) using a variety of high-resolution aerial imagery sources.

Impoundments

Impounded waters include the watershed upstream from documented dam locations and waterfowl impoundments. The data sources for dam locations were Collier and Odum (1989), Moser and Terra (1999), Department of Transportation (2013 data, https://connect.ncdot.gov/resources/gis/pages/gis-data-layers.aspx), Division of Water Resources (2000 data), and USACE obstructions inventory (2008 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. Waterfowl impoundments were verified visually using a variety of high-resolution aerial imagery sources.

Bridge constrictions

This data set was created by hand by modifying the DCM shoreline data for Region 3. Many segments of shoreline were not complete and contained gaps. In order to turn the line into a polygon feature, the gaps had to be closed by hand. In most cases, the gap was connected by a straight line. In cases where the gap was substantial, orthoimagery was traced at a 1:500 scale by hand to more accurately reflect the shoreline. The line features were then dissolved and converted to a polygon using the "feature to polygon" tool in ArcToolbox. This created a r3_LandAndWater data layer. Features were categorized as water or land (Type). Finally, this water layer was created by selecting for water only (where Type=water).

Bulkheads and riprap

Shoreline type was extracted from the North Carolina Division of Coastal Management's 2012 estuarine shoreline data (McVerry 2012). Alteration was rated as the ratio of the linear distance of stabilized structures to the linear distance of shoreline within an assessment hexagon. Stabilized structures were defined as "bulkheads" and "riprap". Alteration weight was higher for bulkheads than for riprap because bulkheads have a greater negative impact on the shorelines than riprap.

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

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. This layer does not include channels dredged by the DWR or private channels dredged for deep-water access, though these areas may be included in the canals and boat basins layer.

Ditched/Drained

For wetland polygon features, partially drained wetland areas were derived using the "drained" attribute in the U.S. Fish and Wildlife Service's National Wetlands Inventory dataset. For the linear stream features, the "ditched" classification in the high resolution National Hydrography dataset was used to select all ditched stream linear features.

Canals and boat basins

This alteration factor included very long and straight polygon features (obvious canals for navigation) or relatively short and straight elongate polygons with no upstream hydrology (short, water access canals or boat basins). Some of the delineated boat basins could also overlap with marinas. This file was created by clipping out portions of the Division of Marine Fisheries 24K_jurisdictional_waters that appeared to be excavated canals or boat basins. Some modifications were made by hand to remove areas that were for obviously for drainage instead of navigation when compared with 2012 imagery data. Additional areas were added based on obvious canals and boat basins observed through various aerial imagery sources.

Water quality and land use alterations

Major NPDES

This factor was derived from NPDES sites locations provided by DWR (2006 data). One location that was known to be erroneous (Camp Lejeune advanced wastewater treatment plant) from this source was corrected. Major NPDES sites in the region were wastewater treatment plants for Camp Lejeune, Morehead City, and Beaufort. The shellfish sanitation section of DMF has conducted dye studies that determined the extent of the impact of these facilities, thus they were matched to shellfish sanitation

closure areas associated with these facilities.

Minor NPDES

The impact of minor NPDES sites was difficult to quantify because the environmental impact of minor NPDES sites is variable and it is difficult to determine the area of influence for a point source without a detailed hydrologic model. Therefore, we decided to summarize minor NPDES sites by hydrologic unit to approximate the measure of alteration. The number of 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.

Marinas

Wildlife Resources Commission and DMF Shellfish Sanitation data on marina locations and numbers of slips were combined to make one dataset of all facilities with > 10 slips. The DMF Shellfish Sanitation Section has determined the area of influence for marinas or groups of marinas on a creek that subject to buffer rules for shellfish sanitation reasons. Areas within these buffers are closed to shellfishing. These closure areas were used to define the area of impact for marinas in this analysis. The total number of slips at marina facilities were aggregated by closure area and divided by the amount of area in the closed area to get a slips/acre metric. This metric was scaled to the maximum value occurring in Region 3.

Animal operations

Locations and size of animal operations were obtained for poultry, swine, and cattle operations. Swine and cattle operation information came from DENR's animal operations permits as of January 2013 (Division of Water Resources (DWR), Animal Feeding Operations Unit, available from the DWR website at http://portal.ncdenr.org/web/wq/animal-facility-map). Poultry data was downloaded from the American Environmental Geographic Information System (AEGIS; available at http://www-geography.jsu.edu/, downloaded 08/2013), which contains point locations of animal feeding operations identified through aerial photography. The poultry data were examined; however, there were no poultry operations located within Region 3. All animal operations within the Region 3 were determined to be swine operations.

The amount of nitrogen runoff generated by each operation was calculated based on accepted values of nitrogen excreted per animal for each type of operation (McNaught et al. 2010). The nitrogen load for all animal operations was totaled for each hydrologic unit and scaled relative to the maximum nitrogen load associated with animal operations in Region 3. Each value was expressed as a percent of the maximum nitrogen load per 12-digit hydrologic unit code.

Mining discharge

Mining was included as an alteration factor because mining operations discharge fresh water into adjacent waterways. Mine inventory data was obtained from the DENR Division of Energy, Mineral, and Land Resources that was produced in January 2012. Information on which of those mines discharged into adjacent waterways was obtained from DWR; however, it was not possible to determine the amount of discharge each mine produced. Thus, the number of mines in each hydrologic unit (HU) were determined and scaled to the maximum number of discharging mines per HU in the region.

Developed land use

This alteration factor was derived from the National Oceanic and Atmospheric Administration's 2010 C-CAP Southeast Region Land Cover dataset using the open space, low-, medium-, and high-intensity development classifications. The total area of developed land-use within each 12-digit U.S. Geological Survey hydrologic unit (HU) was calculated and scaled to the maximum proportion of developed land use found within a HU in the study region. A greater proportion of developed land within a HU suggests greater nutrient and chemical loadings from non-point development sources.

Agricultural land use

This alteration factor was derived from the National Oceanic and Atmospheric Administration's 2010 C-CAP Southeast Region Land Cover dataset using the cultivated crops and pasture/hay classifications. The total area of agricultural land-use within each 12-digit U.S. Geological Survey hydrologic unit (HU) was calculated and scaled to the maximum proportion of developed land use found within a HU in the study region. A greater proportion of agricultural land within a HU suggests high nutrient and chemical loadings from non-point agricultural sources.

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 DMF. Areas that are closed due to marina buffer rules were removed from this layer to avoid duplication with the marina alteration layer.

Piers, docks, and bridges

Shoreline structures were obtained from the North Carolina Division of Coastal Management's 2012 estuarine shoreline structures survey data (McVerry 2012). These areas were considered an impact due to shading open water areas, disturbing the adjacent shoreline, and increased activity in the surrounding areas.

Physical disturbance

Trawling

A dataset depicting areas that are either permanently or temporarily closed to trawling was recently created by DMF for an upcoming amendment to the Shrimp Fisheries Management Plan. This data was used to create a GIS dataset of areas that are open to both permanently and temporarily open to trawling. Areas that were open to trawling were given a higher alteration score because these areas are productive shrimp areas and typically have more trawling activity when they are open (T. Murphy, DMF, personal communication). Unfortunately, data on trawling effort in specific areas is not available at this time.

Mechanical Clam Harvest Areas

Two types of mechanical harvest gear are currently used in North Carolina: the hydraulic escalator

dredge and the clam trawl or "clam kicking" vessel. The hydraulic escalator dredge penetrates the bottom to a depth of about four inches and collects clams as they are forced from the bottom by water pressure and conveyed up the escalator aboard the vessel. In clam trawling or "kicking", clams are dislodged from the bottom with prop wash, and a heavily chained trawl with a cage behind the boat collects the clams (DMF 2008). It is accepted that these mechanical harvest methods can negatively impact submerged aquatic vegetation (SAV) and oyster rocks (Peterson et al. 1987), thus, mechanical harvest of clams is allowed only in certain areas (almost exclusively in Region 3). In addition, some of these areas are open and closed on a rotational basis of either one or two years (Table 4).

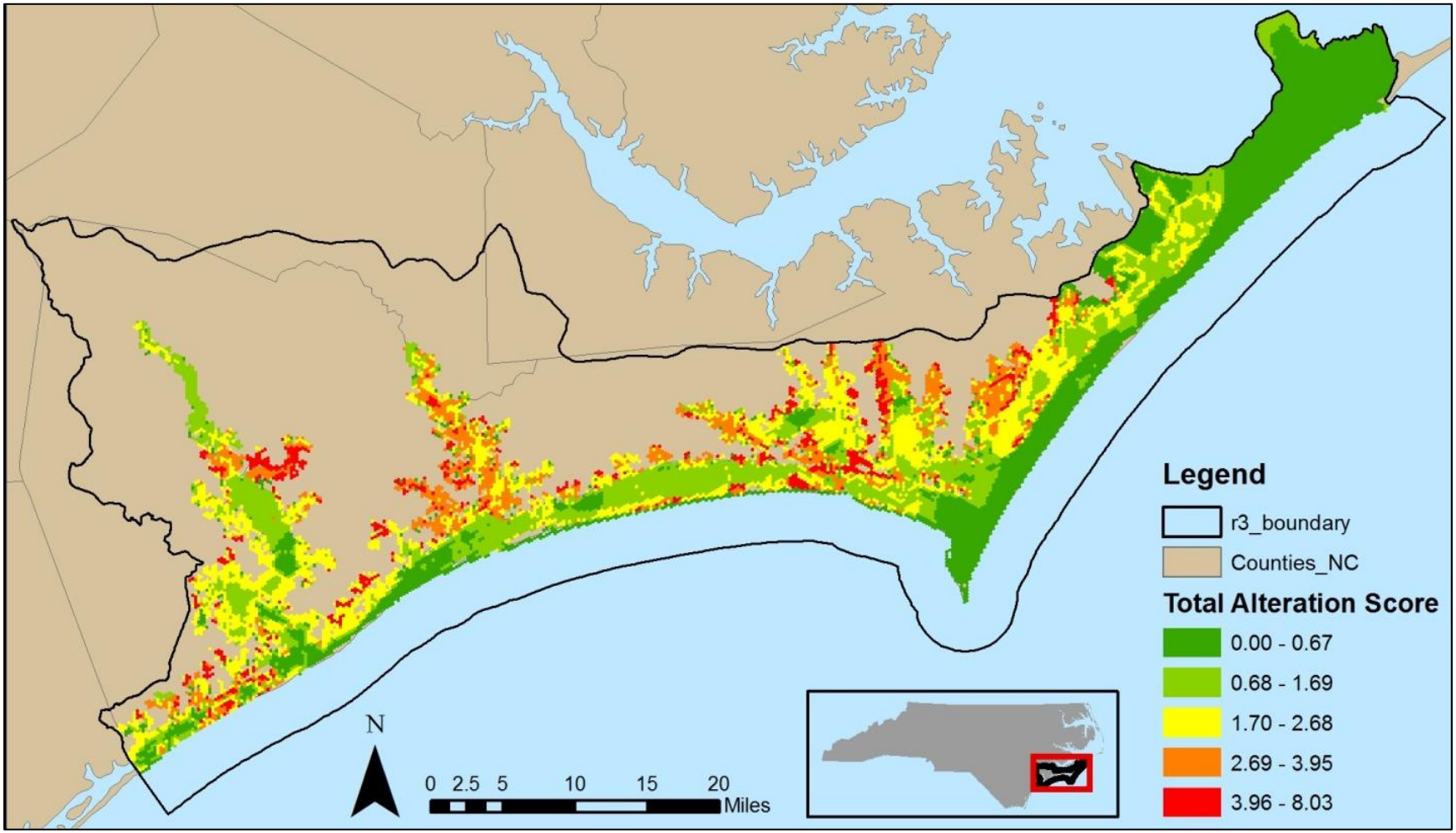
Table 4. Daily mechanical hard clam harvest limits by water body (DMF 2008).

Waterbody	Daily harvest limits	Additional information
Southeastern Pamlico Sound	5,000 clams	Rotates 2 years on and 2 years off with northern Core Sound area. Began in 2001.
Northern Core Sound	5,000 clams	Rotates 2 years on and 2 years off with southeastern Pamlico Sound area. Began in 2001.
Core Sound	5,000 clams	Limit reduced from 6,250 clams per operation in 2001.
North River	3,750 clams	
Newport River	3,750 clams	
Bogue Sound	3,750 clams	
White Oak River	6,250 clams	Rotates one year on and one year off with New River area.
New River	6,250 clams	Rotates one year on and one year off with White Oak River area.
ICW Onslow/Pender County area	6,250 clams	Marker 65 to the BC marker at Banks Channel

Total alteration/cumulative impacts

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

Areas in Core Sound were the least altered along with areas in Bogue Sound, Inland Waterway – Onslow, and portions of New River (Map 4). The most altered areas were in near developed areas such as Jacksonville and Morehead City, the White Oak River, and areas in Down East Carteret County near Open Grounds Farm (Map 4).



Map 4. Total alteration scores for Region 3. 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 30 acres in area, 432 m in diameter, and 216 m in side length. Each run consists of a specified number of iterations. Each iteration considers a new reserve configuration of hexagons by calculating a cost that is based on the success of the program at meeting its targets, the reserve boundary length and the cost of the area considered. Iterations proceed until the change between iterations is minimal or the maximum number of iterations is reached. The number of runs, iterations and BLM can all be specified in the Marxan settings and should be adjusted to attain an appropriate solution for each analysis. An informal sensitivity analysis was conducted for Region 3 (Appendix E), and it was decided to run each scenario for Region 3 500 times with 1,000,000 iterations per run. The BLM was adjusted to 0.01 in order to produce the most efficient solution in terms of cost and area selected between runs.

Lower BLM values produced solutions that were smaller, spatially isolated clusters with less than three hexagons with the exception of Core Sound. The majority of Core Sound behind Core Banks from Cape Lookout to Ocracoke Inlet was consistently chosen in all sensitivity runs (Appendix E). Higher BLM values produced SHAs that were too large for management and consumed too much area (Appendix E). Areas composed of less than 3 adjacent hexagons were considered too small for management and removed from the solution considered in the corroboration stage with the exception of isolated areas of hard bottom offshore in the ocean.

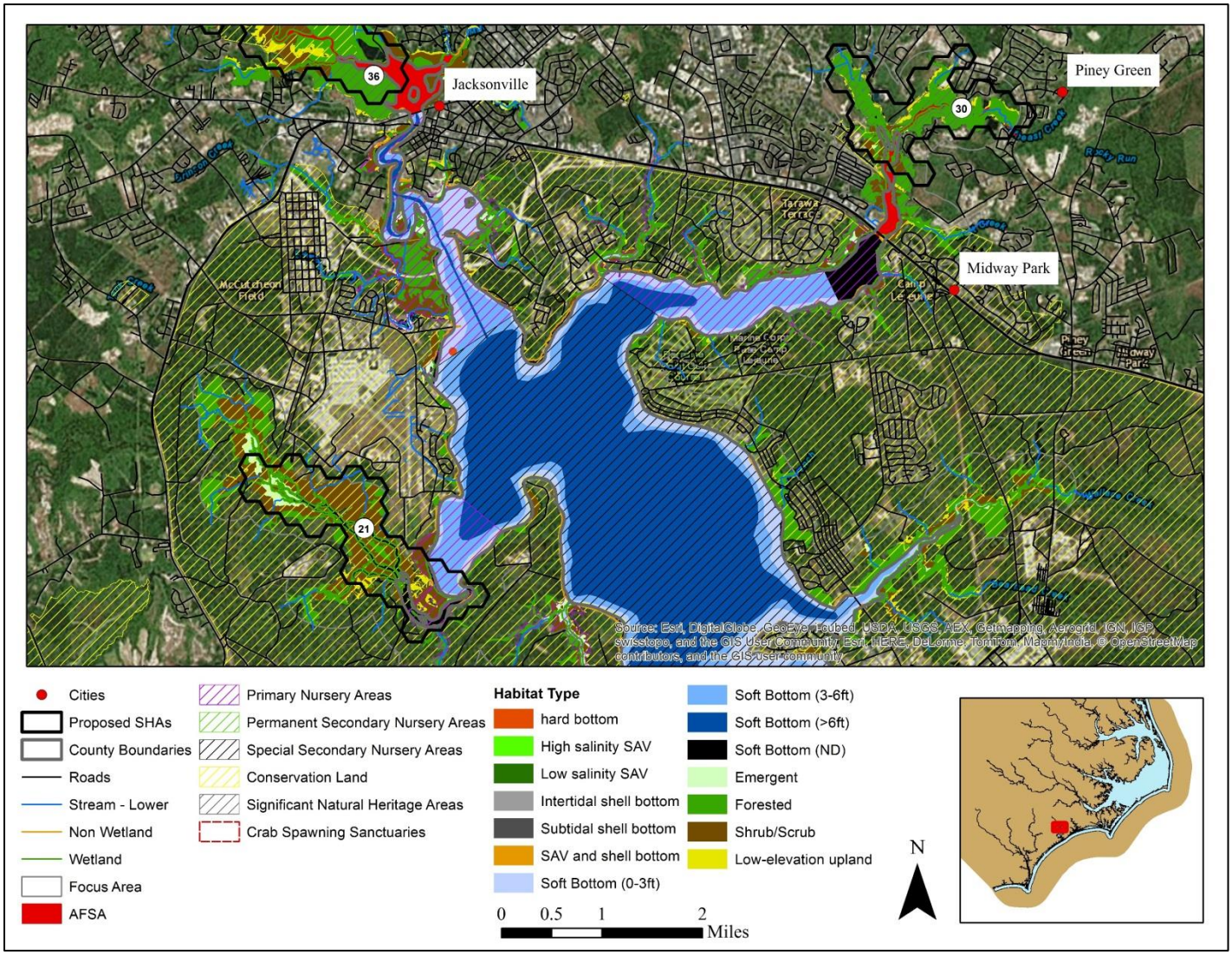
Preliminary Marxan runs were consistently selecting large areas of the ocean with marine soft bottom >6 ft despite the representation level being set at 0%. Hard bottom was removed from the analysis and Marxan was re-run; however, the model continued to select large areas of ocean. Investigation by DMF staff and the advisory committee determined that the most likely cause was that the ocean areas were being selected because the total alteration scores were so much less than those in inside waters and all representation levels were being met for all targets. To solve this problem, the advisory committee decided to remove all hard bottom and marine soft bottom NRTs from the analysis and re-run Marxan with just inside waters. The advisory committee felt that the only areas of the ocean that should be included as a SHA would be known hard bottom locations (except artificial reefs) and areas near inlets. Thus, these areas were added in during the corroboration phase.

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

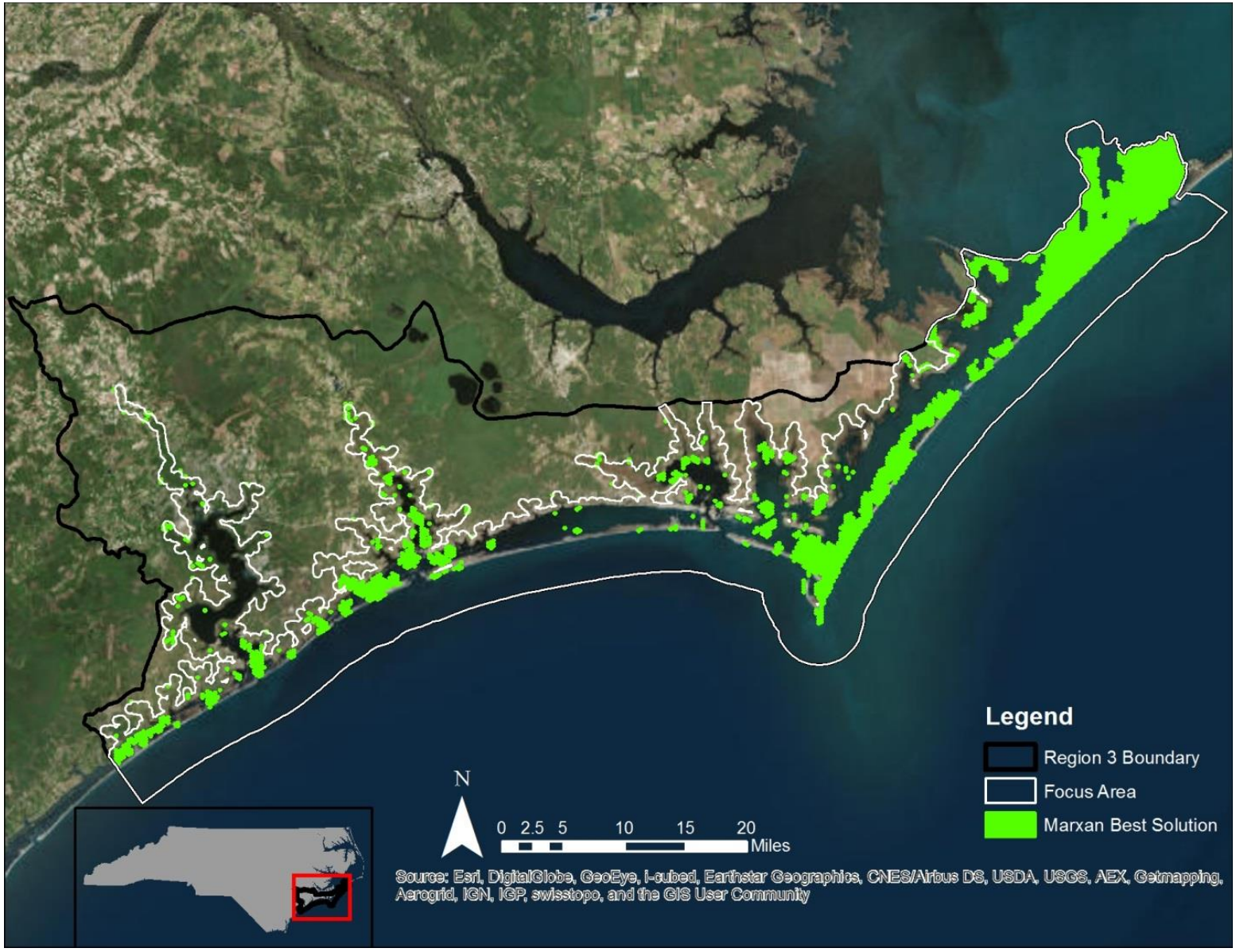
MARXAN RESULTS

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 2). Map 5 depicts the Marxan selections from the best solution with the most efficient BLM. This resulted in a large number of small SHAs that the advisory committee thought would be difficult to manage. As a result, the advisory committee decided to examine the selection frequencies, since high selection frequencies are an indication that an area was not erroneously chosen (Map 6). The committee felt that using hexagons that were selected at least 300 times out of the 500 runs was a good starting point for corroboration (Map 7).

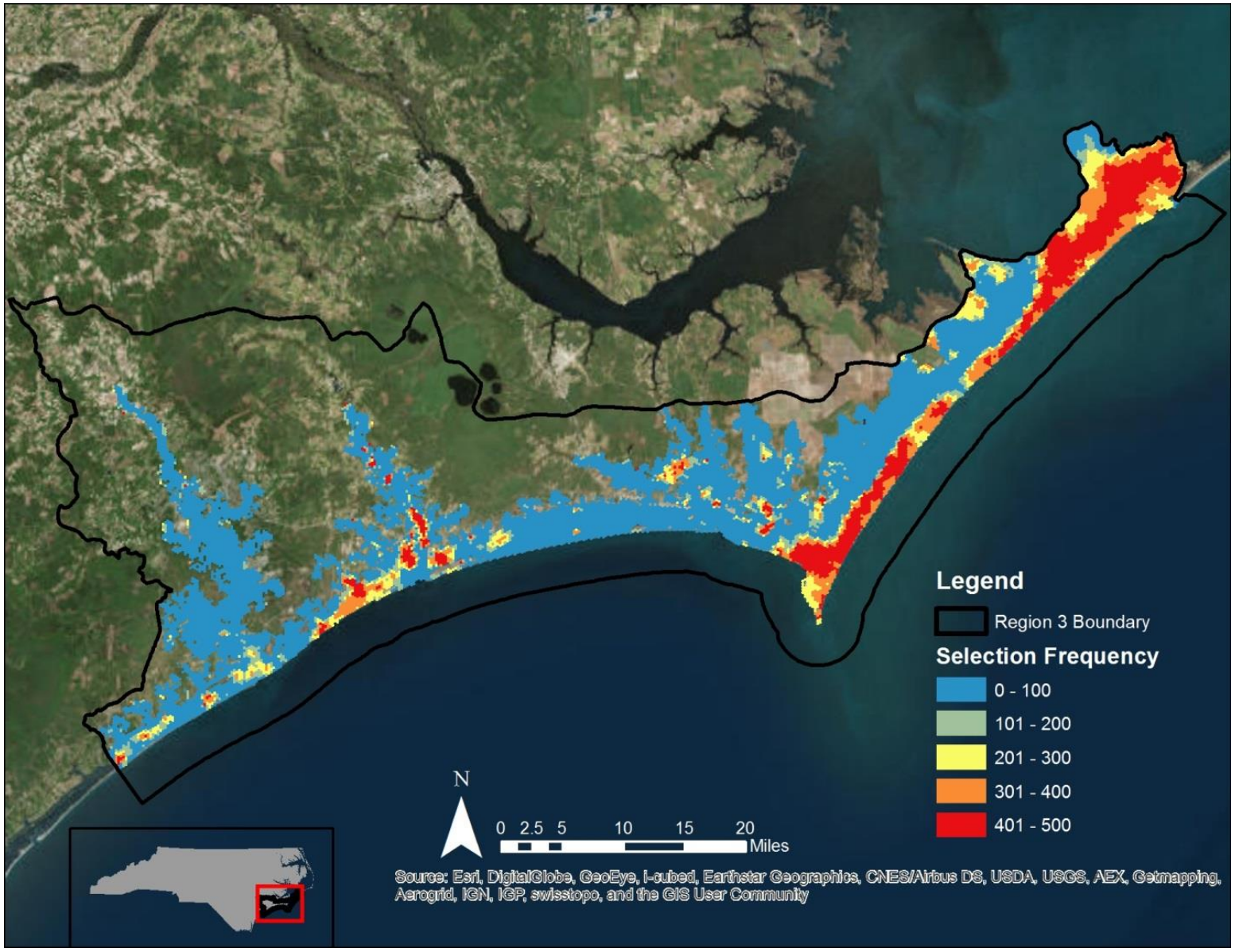
Large areas of Core Sound behind the Core banks were consistently chosen and are known to be ecologically important with large amounts of SAV and very low levels of alteration. Other sizeable areas that were selected were Middle Marsh and North River Marsh in the mouth of North River, the upper area of Newport River, large areas of the White Oak River and Inland Waterway – Onslow; however, almost all of New River was not selected (Map 7). Examination of the habitats mapped in this area showed mostly estuarine soft bottom and wetland habitats, all of which had relatively low representation levels due to their abundance in the region and relative robustness to alterations (



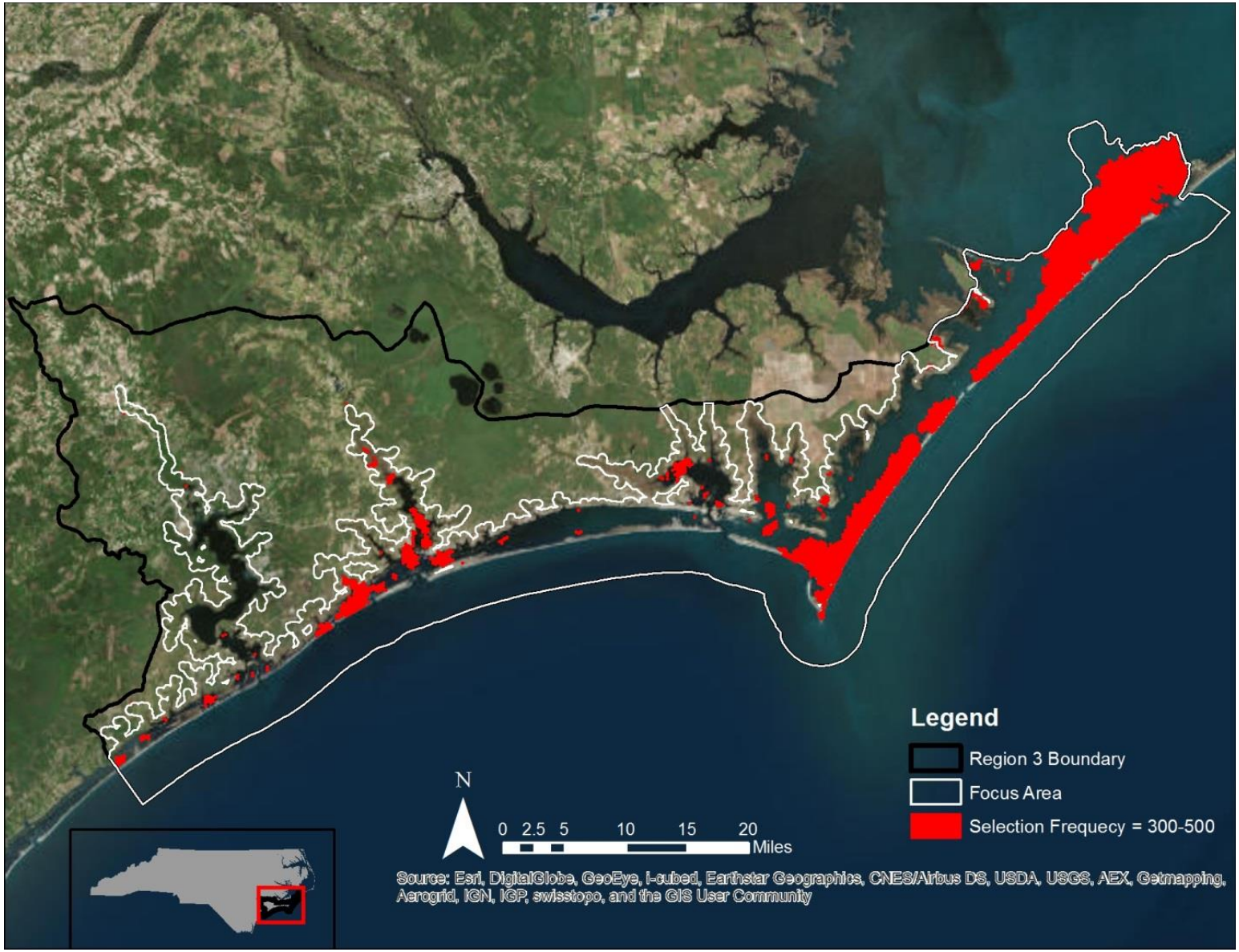
Map 15 and Map 16).



Map 5. Marxan best solution.



Map 6. Marxan selection frequency.



Map 7. Marxan hexagons with a selection frequency of 300-500.

CORROBORATION

The advisory committee reviewed the initial Marxan selections and made expert modifications as needed. The SHA committee grouped individually selected hexagons into manageable polygons for the corroboration and identification process. Modifications to the Marxan selected SHAs were made using an overlay of selected hexagon polygons on digital imagery. The SHA committee examined maps of both the selection frequency and alteration ratings for guidance during the manual selection phase. For each polygon or group of contiguous hexagons, 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.

Criteria to base modifications on included:

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

5. These data are meant to support computer-selected areas and identify important areas omitted by the Marxan analysis. Examples of omitted areas would be a 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.

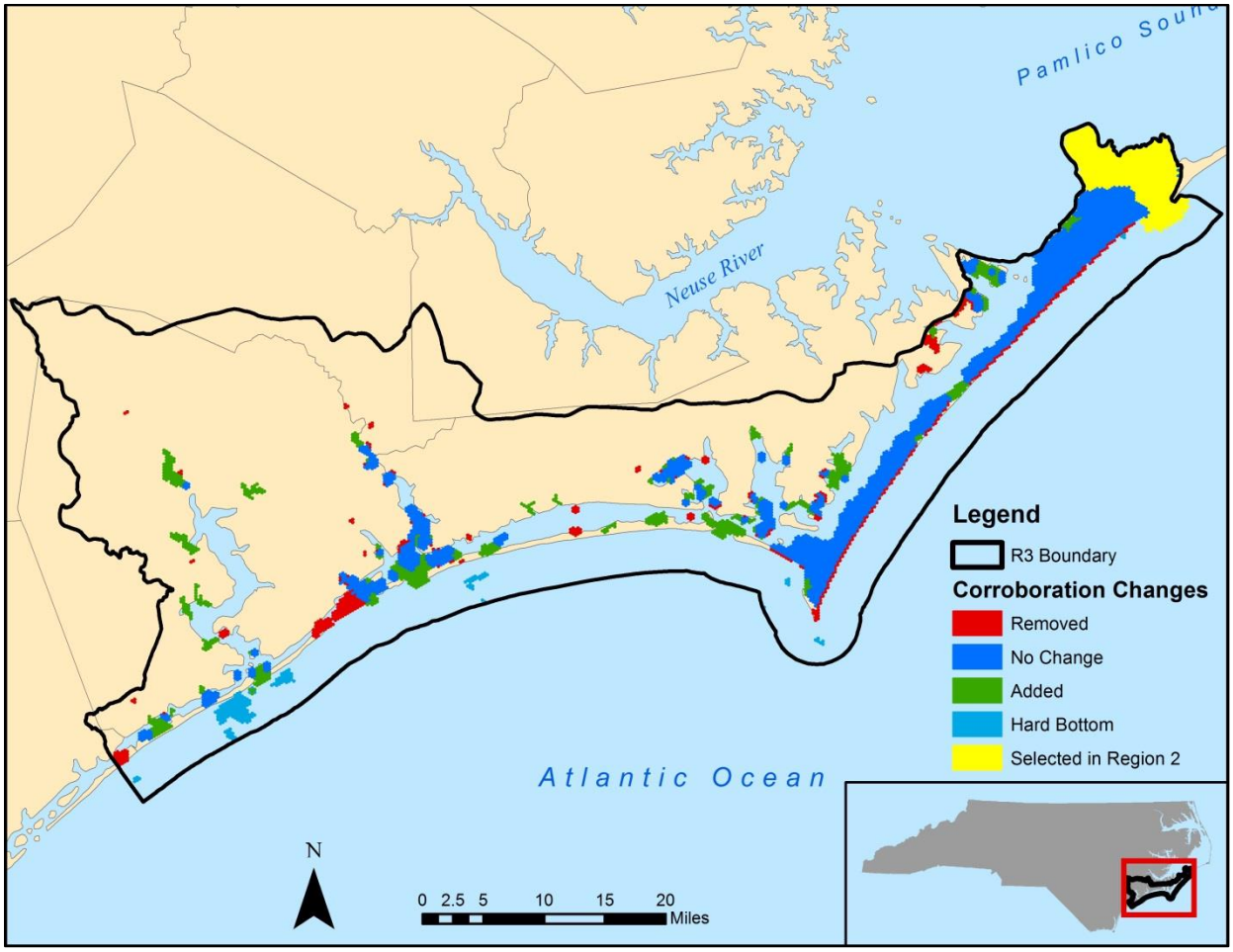
The committee used the criteria listed above to cut, extend, and/or consolidate Marxan clusters within the focus area. Selected hexagons with fewer than three contiguous hexagons were excluded. A large portion of the corroboration focused on the New River area where Marxan selection frequencies were low, but the area is known for its importance to hard clams, shrimp, oysters, southern flounder, spotted seatrout, and red drum (DMF Trip Ticket data). Consolidations were based on avoiding what the group considered over-represented habitats (e.g., 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, some estuarine soft bottom areas were removed to prevent over-

representation of this resilient habitat.

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 large amounts of developed low-elevation uplands were removed (e.g., neighborhoods, shopping malls, etc.). The advisory committee also expanded polygons into some unselected areas that were known to be highly productive for priority species or habitats. The visual assessment was conducted systematically around the region, starting from the southern end at Stump Sound and working north to Ocracoke Inlet. It should be noted that the Ocracoke Inlet area was added by default because that area was already selected as a SHA in the region 2 analysis (DMF 2011). Inlet areas were also added in by default because of their importance to migratory fishes moving in and out of those areas. Modifications made by the advisory committee are displayed in Map 8.

Table 5. Ecological designations and biological data from DENR sampling programs that could be used as an indicator of aquatic habitat condition in Region 3.

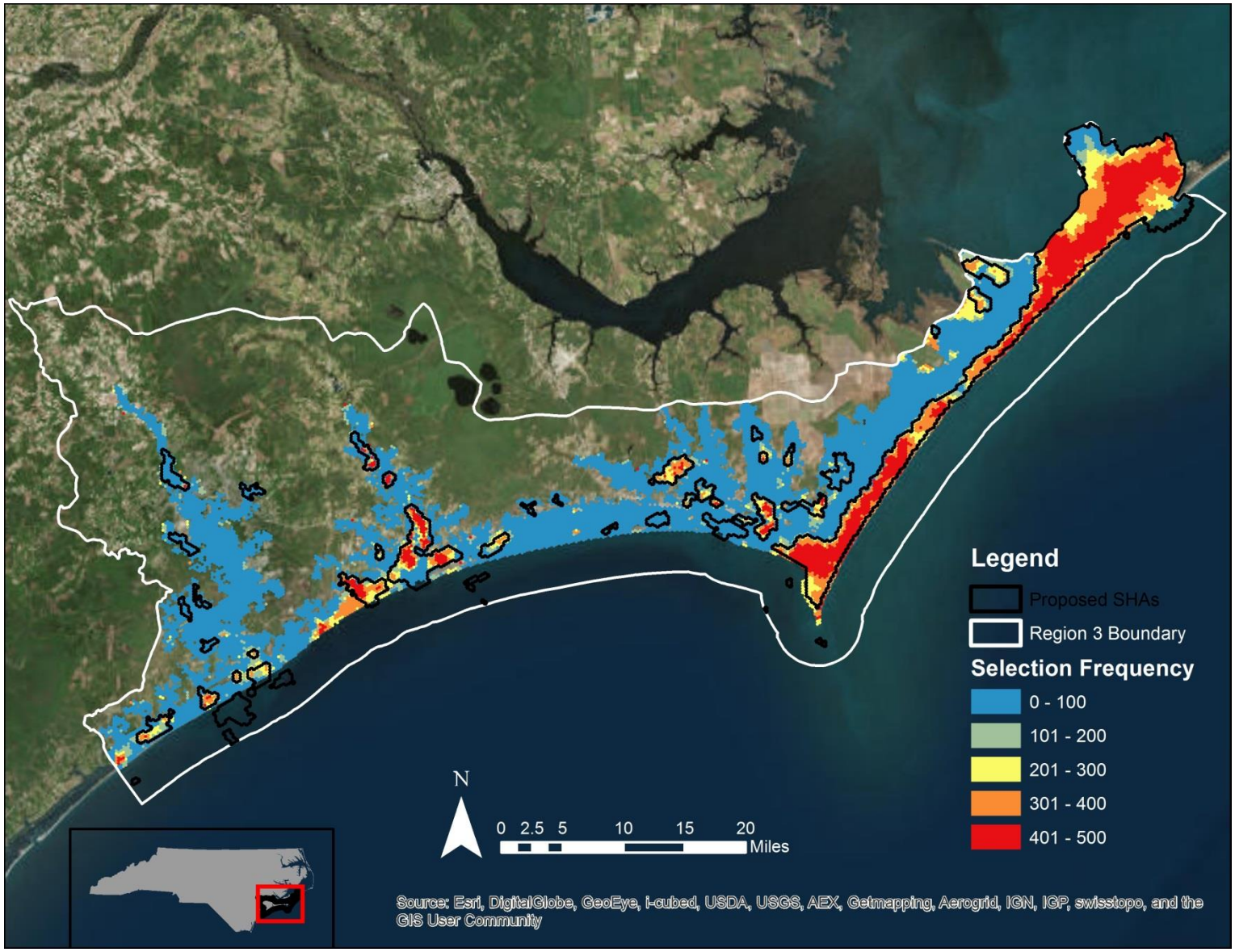
Type	Description	Source
Ecological designations	Anadromous Fish Spawning Areas	MFC designation
	Blue crab spawning sanctuaries	MFC designation
	Estuarine PNAs	MFC designation
	Inland PNAs	WRC designation
	Open shellfish harvesting waters	DMF - SGA classification
	Significant Natural Heritage Areas (aquatic and terrestrial)	Natural Heritage Program designation
	Lands managed for conservation	DENR One NC Naturally
Species/ productivity data	Use support and biotic indices for fish and invertebrates (freshwater streams only) – index values	DWR
	Juvenile estuarine fish	DMF program 120
	Shellfish densities	DMF program 635



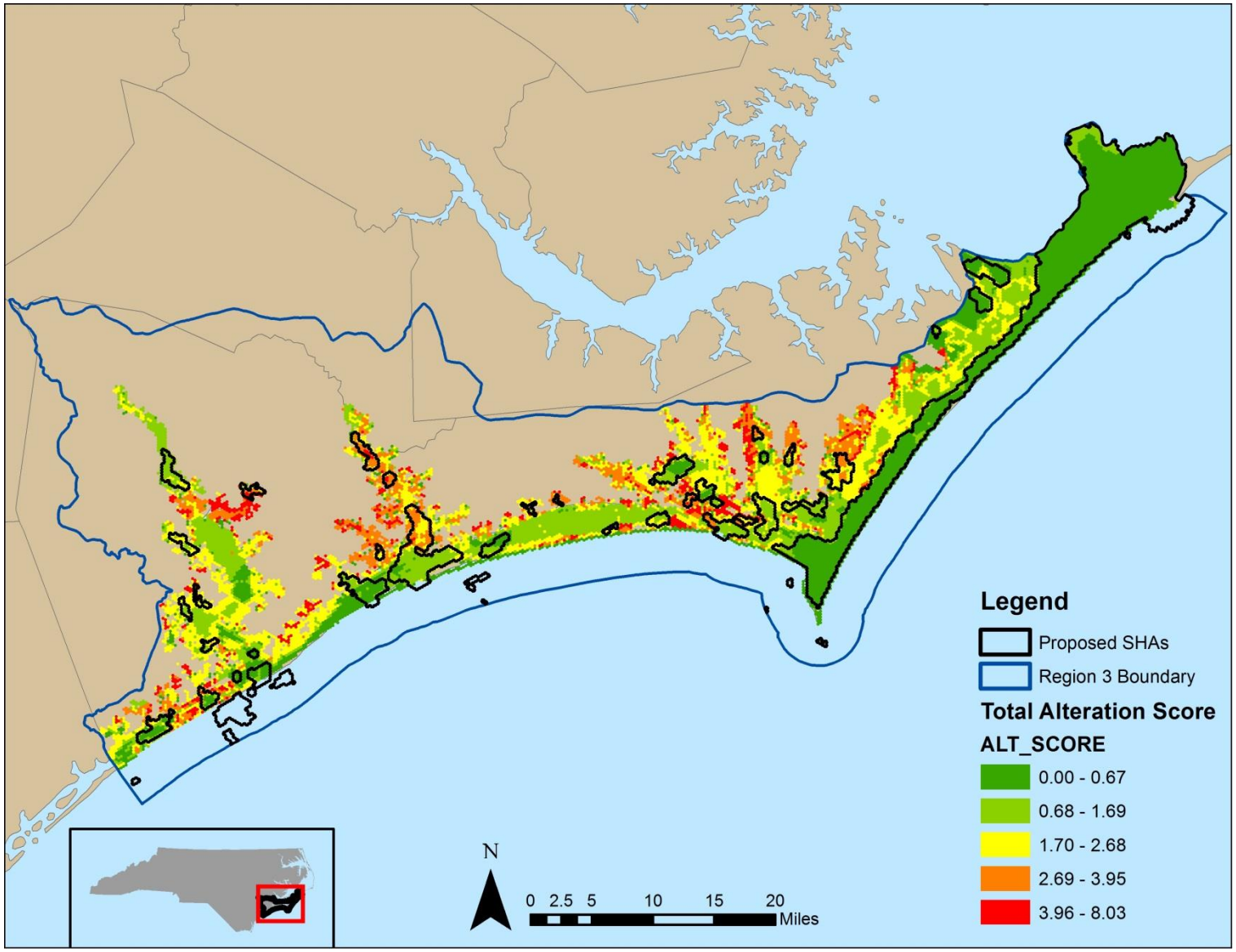
Map 8. Map of corroboration changes made by the advisory committee.

Post-Corroboration Results

Following the corroboration phase, there were a total of 71 discrete areas selected for nomination. This comprises 19% of the focus area. Of that selected acreage, 134,547 acres and 1,390 miles of linear features (streams and shoreline) were included in SHAs (Table 6. Representation levels, target acres, and resulting amounts of natural resource targets.). All targets were met or exceeded except for palustrine soft bottom (0-3 ft), which was close at 98% and only a few acres (Table 6. Representation levels, target acres, and resulting amounts of natural resource targets.). Streams were slightly underrepresented at 94% (Table 6. Representation levels, target acres, and resulting amounts of natural resource targets.). The total miles or acreage of natural resource targets within each SHA is included in Table 7. Distance (mi) of linear features in each Strategic Habitat Area. 7 and Table 8. Amount of habitat (acres) present in each SHA.. The habitat targets that were most exceeded were riverine (0-3 ft), and estuarine (no depth) soft bottom, emergent wetlands, and low elevation uplands. Following groundtruthing, developed portions of low elevation uplands should be omitted. Map 9 and Map 10 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 advisory committee had low selection frequency but low to medium alteration scores.



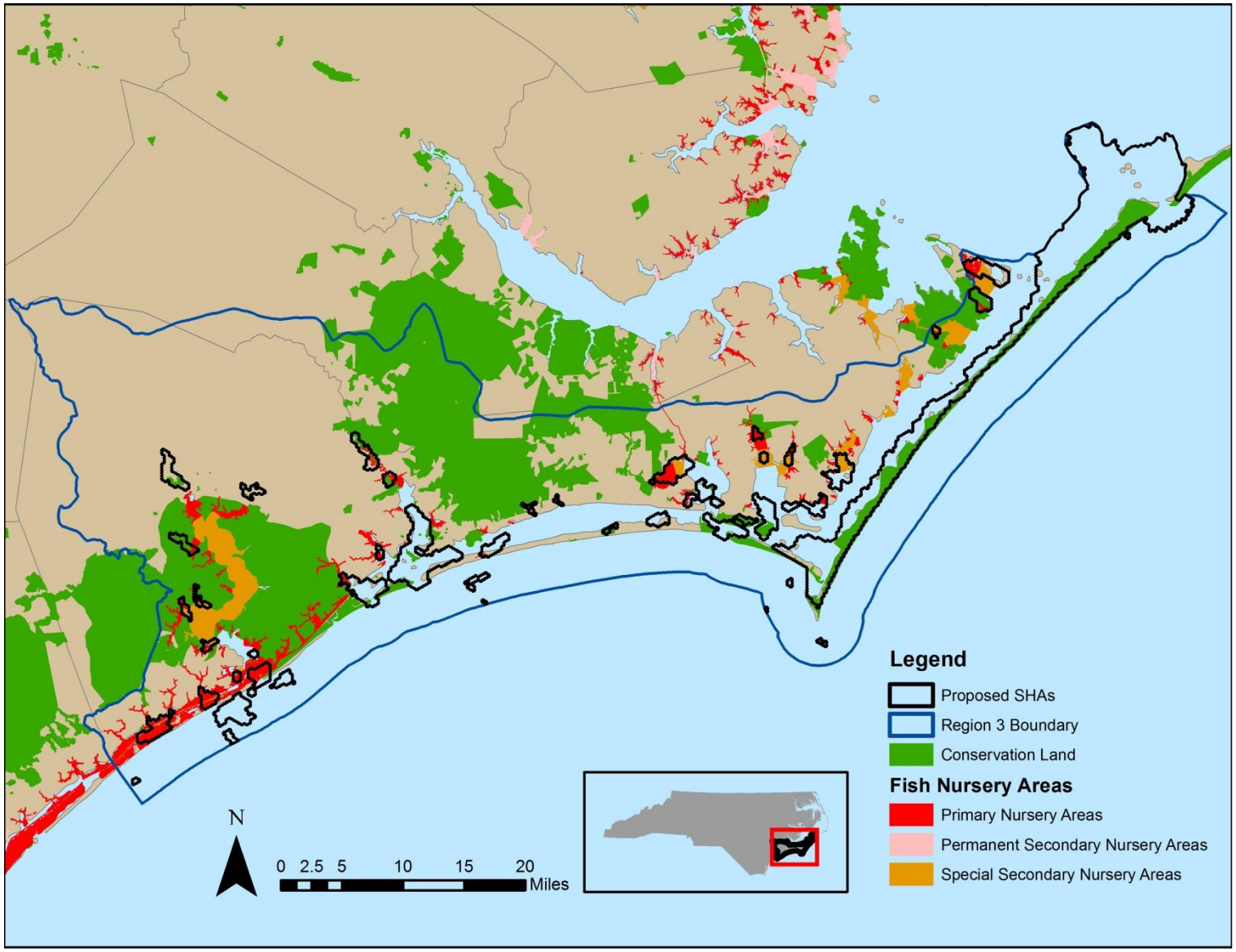
Map 9. SHA nominations after corroboration showing selection frequencies.



Map 10. 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 rivers to the grass beds and ebb tide deltas of the Outer Banks. Selections were scattered throughout the area and concentrated along the back side of Core Banks where almost all of the high salinity SAV was selected. The advisory committee 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. 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. A large amount of subtidal shell bottom (74%) and intertidal oysters (62%) were selected.

Region 3 has an abundance of state and federally protected lands bordering coastal waters Map 11. Of the 134,547 acres selected as SHAs, 26% (35,350 acres) already have some level of protection. Twenty percent (26,325 acres) occur on lands managed for conservation (state, federal, local), 5% (6,805 acres) are located in MFC designated PNAs, and 2% (3,056) are in special secondary nursery areas. Some of the larger conservation lands on mainland side are the Croatan National Forest and Marine Corps Base Camp Lejeune. The area from Cape Lookout North is all undeveloped National Seashore. SHAs within protected conservation lands are basically already protected from degradation associated with development. The remaining 74% (99,197 acres) represent SHA nominations of various conditions that are currently vulnerable to land and/or water based threats.



Map 11. Post-corroboration SHA nominations, noting occurrence of state, federal, and private (land trust) conservation lands and MFC designated PNAs.

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 6. Representation levels, target acres, and resulting amounts of natural resource targets.

Habitat type	Natural resource target	Total acres/mi in focus area	Rep level (%)	Target (acres/mi)	Amount selected after corroboration (acres/mi)	% Target
	Polygon habitat types (all area values are in acres)					
Hard bottom	Hard bottom*	3,839	-	-	3,528	-
SAV	High salinity SAV	32,265	60	19,359	25,633	132%
	Low salinity SAV	33	90	30	33	110%
Shell bottom	Intertidal shell bottom	1,357	50	679	872	128%
	Subtidal shell bottom	2,370	60	1,422	1,706	120%
SAV & shell bottom	SAV & shell bottom	349	60	209	297	142%
Creeks & Rivers	Riverine soft bottom (0-3ft)	5	30	1	5	500%
	Riverine soft bottom (3-6ft)	4	0	0	4	-
	Riverine soft bottom (ND)	331	0	0	210	-
Shallow soft bottom	Palustrine soft bottom (0-3ft)	12	20	2	3	150%
	Palustrine soft bottom (ND)	215	0	0	77	
	Estuarine (0-3ft)	76,823	30	23,047	33,464	145%
	Estuarine (3-6ft)	42,421	20	8,484	15,606	184%
	Estuarine (ND)	10,450	10	1,045	4,974	476%
	Marine (0-3ft)*	4,611	-	-	1,267	-
	Marine (3-6ft)*	4,406	-	-	806	-
Deep soft bottom	Estuarine (>6ft)	44,004	0	0	17,587	-
	Marine (>6ft)*	242,402	-	-	6,268	-
Wetland	Emergent	39,033	10	3,903	13,816	354%
	Forested	23,181	10	2,318	2,434	105%
	Shrub/scrub	10,665	0	0	3,606	-
Low-elevation upland	Low-elevation upland	7,733	10	773	2,567	332%
TOTAL AREA w/o hard bottom & ocean		**546,511**		**61,274**	**134,763**	**220%**
TOTAL AREA w/ hard bottom & ocean		**693,706**				
	Line habitat types (all distance values are in miles)					
Streams	Streams (low elevation)	621	10	69	66	96%
Low-elevation upland	Non-wetland shoreline	423	10	42	85	202%
Wetland shoreline	Wetland shoreline	2,274	40	909	1,267	139%
TOTAL DISTANCE		**3,384**		**1,021**	**1,418**	**139%**

*Not included in Marxan calculations

Table 7. Distance (mi) of linear features in each Strategic Habitat Area.

SHA ID	Non Wetland Edge	Stream - Lower	Wetland Edge	Total
2	3.93	3.06	33.08	40.08
6	2.17	7.82	15.03	25.01
7	0.38		1.45	1.83
9	4.81	3.37	35.89	44.06
10	0.28		0.69	0.97
11	2.44	1.01	2.92	6.37
14	1.76	1.89	0.74	4.39
15	1.87	1.28	4.50	7.65
18	4.93	1.70	132.31	138.95
20	0.46	0.03	9.62	10.11
21	1.49	2.18	17.61	21.29
22	0.10		7.31	7.42
23	0.40	0.09	14.12	14.60
24	4.40	0.06	0.37	4.84
25	18.15	4.51	322.78	345.44
26	0.22	0.59	9.06	9.87
27	0.24	0.05	5.83	6.12
28	0.04	0.33	108.34	108.72
29	4.04	0.64	12.92	17.59
30	0.20	2.34	11.68	14.22
31	0.10	2.00	33.88	35.98
32	0.01	6.94	8.83	15.79
33	0.37	1.68	12.35	14.41
34	1.75	1.39	19.92	23.06
35			0.01	0.01
36	0.66	2.30	21.09	24.05
37	0.90	0.27	4.86	6.02
38	0.06	7.90	16.39	24.35
39		1.37	4.47	5.84
40	1.02	0.49	7.39	8.91
41	2.14	1.02	28.81	31.98
43	24.01	8.49	330.05	362.55
44	0.08	0.22	2.62	2.92
45	0.02	0.02	16.26	16.30
46	1.08	0.46	6.02	7.56
47	0.26	0.61	4.36	5.23
48		0.23	3.06	3.28

Table 8. Amount of habitat (acres) present in each SHA.

		SHA ID									
Habitat Type	**Natural Resource Target**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Hard bottom	Hard bottom*	2		234	2447	2			615		
SAV	High salinity SAV		1				1	0		10	7
	Low salinity SAV										
Shell bottom	Intertidal shell bottom		20				12	1		2	
	Subtidal shell bottom		26				54	13			9
SAV & shell bottom	SAV & shell bottom						2			0	0
Creeks & Rivers	Riverine soft bottom (0-3ft)										
	Riverine soft bottom (3-6ft)										
	Riverine soft bottom (ND)										
Shallow soft bottom	Palustrine soft bottom (0-3ft)		0				0				0
	Palustrine soft bottom (ND)		0				0				0
	Estuarine (0-3ft)		1295				511	229		335	136
	Estuarine (3-6ft)		44				23			3	57
	Estuarine (ND)		65				39	2		98	2
	Marine (0-3ft)*				0					221	
	Marine (3-6ft)*				10					207	
Deep soft bottom	Estuarine (>6ft)		30				14			4	
	Marine (>6ft)*	148		192	844	208			285	86	
Wetland	Emergent		354				218	6		406	2
	Forested		29				10				
	Shrub/scrub		65				27	1		22	3
Low-elevation upland	Low-elevation upland		87				32	3		40	22
	TOTAL	150	2015	426	3300	210	943	255	900	1434	240

		SHA ID									
Habitat Type	**Natural Resource Target**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Hard bottom	Hard bottom*		23	10			1	2		182	
SAV	High salinity SAV	125			22	71			10		
	Low salinity SAV										
Shell bottom	Intertidal shell bottom	2							135		27
	Subtidal shell bottom								43		22
SAV & shell bottom	SAV & shell bottom								0		
Creeks & Rivers	Riverine soft bottom (0-3ft)										
	Riverine soft bottom (3-6ft)										
	Riverine soft bottom (ND)										
Shallow soft bottom	Palustrine soft bottom (0-3ft)	0			0	0			0		
	Palustrine soft bottom (ND)	0			0	1			0		
	Estuarine (0-3ft)	95			118	112			704		
	Estuarine (3-6ft)	18			68	5			51		
	Estuarine (ND)	6			6	8			224		225
	Marine (0-3ft)*								157		
	Marine (3-6ft)*								94		
Deep soft bottom	Estuarine (>6ft)	30			15	5			18		
	Marine (>6ft)*		157	43			59	148	23	448	
Wetland	Emergent	33			23	21			1164		16
	Forested	5			21	42			21		
	Shrub/scrub	8			30	42			22		
Low-elevation upland	Low-elevation upland	22			21	14			37		8
	TOTAL	341	180	53	324	321	60	150	2703	630	299

		SHA ID									
Habitat Type	**Natural Resource Target**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Hard bottom	Hard bottom*				1						
SAV	High salinity SAV		422			1125	37	12	340	285	
	Low salinity SAV										
Shell bottom	Intertidal shell bottom		5	37	0	166	34	42	156	7	
	Subtidal shell bottom			30	1	886	0	21	91	112	
SAV & shell bottom	SAV & shell bottom		3			143	4	11	11	61	
Creeks & Rivers	Riverine soft bottom (0-3ft)										
	Riverine soft bottom (3-6ft)										
	Riverine soft bottom (ND)										
Shallow soft bottom	Palustrine soft bottom (0-3ft)			0							
	Palustrine soft bottom (ND)	4		0		0					16
	Estuarine (0-3ft)	15	713	156	399	2167	87	139	1121	522	
	Estuarine (3-6ft)	39	1	7	222	283	14	2	195	93	
	Estuarine (ND)	135	7	49	37	2383	10	5	185	25	32
	Marine (0-3ft)*				23	327					
	Marine (3-6ft)*				14	207					
Deep soft bottom	Estuarine (>6ft)			8	1070	224	42		233	94	
	Marine (>6ft)*				294	0					
Wetland	Emergent	44	94	119	17	1357	98	66	306	71	4
	Forested	76		7		11		0		2	285
	Shrub/scrub	452	4	25	5	68	0	0	1	0	46
Low-elevation upland	Low-elevation upland	38	7	47	64	342	4	17	2	59	39
	TOTAL	803	1256	484	2148	9690	329	317	2642	1332	423

		SHA ID									
Habitat Type	**Natural Resource Target**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Hard bottom	Hard bottom*										
SAV	High salinity SAV	23		3	344			4			2
	Low salinity SAV		19						13		
Shell bottom	Intertidal shell bottom	42		27	2			16		3	
	Subtidal shell bottom	1		142	94	17		30		18	
SAV & shell bottom	SAV & shell bottom			10	8			2			
Creeks & Rivers	Riverine soft bottom (0-3ft)						5				
	Riverine soft bottom (3-6ft)						4				
	Riverine soft bottom (ND)						62		148		
Shallow soft bottom	Palustrine soft bottom (0-3ft)			0	0		2	0			
	Palustrine soft bottom (ND)		0	0	0		46	0	8		0
	Estuarine (0-3ft)	389		1471	824	283	27	264		202	231
	Estuarine (3-6ft)	48		446	608		5				
	Estuarine (ND)	45	164	7	42	0	2	3	16	4	24
	Marine (0-3ft)*										
	Marine (3-6ft)*										
Deep soft bottom	Estuarine (>6ft)	50									
	Marine (>6ft)*										
Wetland	Emergent	473	193	151	227	0	1	83	238	158	300
	Forested		11	52	43		1007	17	130		426
	Shrub/scrub	14	123	1	9		373	22	840		290
Low-elevation upland	Low-elevation upland	7	10	10	54		80	15	8		3
	TOTAL	1093	521	2320	2256	300	1612	456	1400	385	1276

		SHA ID							
Habitat Type	**Natural Resource Target**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**
Hard bottom	Hard bottom*		7	1					
SAV	High salinity SAV	372		22169	59	178	3	2	6
	Low salinity SAV								
Shell bottom	Intertidal shell bottom			105	3	17	10	2	
	Subtidal shell bottom	18		58		2	9	9	
SAV & shell bottom	SAV & shell bottom			36	0	7			
Creeks & Rivers	Riverine soft bottom (0-3ft)								
	Riverine soft bottom (3-6ft)								
	Riverine soft bottom (ND)								
Shallow soft bottom	Palustrine soft bottom (0-3ft)						0		
	Palustrine soft bottom (ND)	0					0	0	
	Estuarine (0-3ft)	1218		19154	18	311	72	35	112
	Estuarine (3-6ft)	414		12825	1	108			26
	Estuarine (ND)	70		1014	6	17	4	5	6
	Marine (0-3ft)*		3	534					
	Marine (3-6ft)*		16	258					
Deep soft bottom	Estuarine (>6ft)	28		15701		10			12
	Marine (>6ft)*		64	3271					
Wetland	Emergent	653		6436	55	280	26	21	104
	Forested	32		130	3		57	17	
	Shrub/scrub	35		1057	10	7	2		
Low-elevation upland	Low-elevation upland	15		1412	23	2	14	6	1
	TOTAL	2856	90	84162	177	941	197	96	266

FINAL STRATEGIC HABITAT AREA NOMINATIONS

Strategic Habitat Area units are described below (numbering is not sequential) beginning in Stump Sound and moving up the coast to Ocracoke Inlet. Strategic Habitat Areas with average alteration scores less than 1.0 and selection frequencies greater than 200 (on a scale of 0–500) represent sites with the least extent of alteration and high ecosystem value. In some cases, areas without these criteria were still selected as SHAs due to other outstanding features.

The following is a list of final SHA nominations grouped by area. Map 12 through Map 27 follow showing the location of each SHA.

Stump Sound, Onslow Waters

SHA #1	**Hard bottom off Surf City (1.6 mi SE of Surf City)**
Description	Likely natural hard bottom
Acres	150
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	Trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Reliability = 12/15, Moderate relief (0.5-2.0 m)

SHA #2	Stump Sound Area
Description	Stump Sound and lower portions of Turkey Creek and Kings Creek, part of Everett Bay
Acres	2220
Prominent Habitats	Emergent wetlands and shrub/scrub wetlands, estuarine soft bottom 0-3 ft, non-wetland edge, wetland edge, subtidal shell bottom, streams (low elevation)
Ecological Designations	PNA, SSNA
Conservation Lands	Permuda Island Coastal Reserve (state); Stump Sound (NCCF) Preserve (private)
Water Quality Ratings	mostly impaired
Water Quality Classifications	ORW, HQW, SA
Fish Data	Spot in PGM 120. Core station just south in Everett Bay
Prominent Alterations	canals and boat basins, dredged channels, drained wetlands, development, trawling (temporarily opened), mechanical clam harvest area, riprap, development, agriculture, prohibited shellfish harvest
Average Total Alteration Score	0.97
Average Selection Frequency	167
Notes	Overall, highly productive subtidal and intertidal oyster reefs, extensive marsh. King's Creek noted for healthy intermix of habitats, productive for red drum, spotted sea trout, blue crab, shrimp, spot

SHA #3	Hard bottom off North Topsail Beach (4.5 nmi SSW of New River Inlet)
Description	Likely natural hard bottom
Acres	426
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	N/A
Average Total Alteration Score	N/A
Average Selection Frequency	trawling (permanently open)
Notes	Reliability = 13/15, High relief (>2.0 m)

SHA #4	Hard bottom off North Topsail Beach (2.7 nmi SW of New River Inlet)
Description	Likely natural hard bottom
Acres	3,300
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	SNHA
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	None
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Reliability = 12/15, High relief (>2.0 m), contains AR-350, SNHA - New River Inlet Outcrop, C rating = unranked, R rating = unranked

SHA #5	Hard bottom off North Topsail Beach (1.3 nmi SW of New River Inlet)
Description	Likely natural hard bottom
Acres	210
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Reliability = 14/15, Low relief (<0.5 m), NOAA Data from fish trawl

SHA #6	Alligator Bay
Description	Alligator Bay and the mouth of Mill Creek
Acres	1,110
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 ft, subtidal shell bottom, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA, SSNA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	ORW, HQW, SA
Fish Data	pgm 120 (CORE)
	spot and shrimp
Prominent Alterations	canals and boat basins, dredged channels, ditching, drained wetlands, prohibited shellfish harvest, trawling (temporarily opened)
Average Total Alteration Score	1.44
Average Selection Frequency	215
Notes	Productive subtidal oysters, two Shellfish/Seed Management Areas

New River

SHA #7	Chadwick Bay
Description	Chadwick Bay and Rose Point
Acres	300
Prominent Habitats	Estuarine soft bottom 0-3 ft, subtidal shell bottom, non-wetland edge, wetland edge
Ecological Designations	PNA, SSNA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	pgm 120
	spot and shrimp
Prominent Alterations	bulkheads, drained wetlands
Average Total Alteration Score	0.42
Average Selection Frequency	262
Notes	Submerged aquatic vegetation, productive for shrimp

SHA #8	Hard bottom off Onslow Beach (1.7 nmi E of New River Inlet)
Description	Likely natural hard bottom
Acres	900
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	None
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Moser and Taylor polygon; in region military training occurs in (live ordinance potentially

SHA #9	New River Inlet
Description	New River Inlet, Wards Channel, Hell Gate Creek
Acres	1,590
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 ft, marine soft bottom 0-3 ft and >6 ft, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA, SNHA
Conservation Lands	Camp Lejeune (federal)
Water Quality Ratings	half impaired and half supporting
Water Quality Classifications	HQW, SA
Fish Data	No
Prominent Alterations	trawling (permanently open), trawling (temporarily opened), mechanical clam harvest area
Average Total Alteration Score	0.53
Average Selection Frequency	191
Notes	SNHA - Camp Lejeune New River Inlet, owned by USDOD, C rating = high, R rating = very high; submerged aquatic vegetation in estuarine waters

SHA #10	New River - Traps Bay
Description	Part of Traps bay west of Corn Landing and Cedar Point
Acres	240
Prominent Habitats	Estuarine soft bottom 0-3 ft and 0-3 ft, low-elevation uplands, non-wetland edge, wetland edge
Ecological Designations	SNHA
Conservation Lands	None
Water Quality Ratings	supporting
Water Quality Classifications	HQW, SA
Fish Data	No
Prominent Alterations	development
Average Total Alteration Score	0.28
Average Selection Frequency	224
Notes	SNHA - New River Inlet Bird Nesting Islands, owned by NCWRC, C rating = moderate, R rating = general

SHA #11	Everett Creek
Description	New River and the mouth of Everett Creek (NW of Hwy. 172)
Acres	510
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3, 3-6, and >6 ft, high salinity SAV, low-elevation uplands, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA, SSNA
Conservation Lands	Camp Lejeune (federal)
Water Quality Ratings	half impaired and half supporting
Water Quality Classifications	HQW, SA
Fish Data	No
Prominent Alterations	bulkheads, drained wetlands, prohibited shellfish harvest area, trawling (temporarily opened)
Average Total Alteration Score	1.96
Average Selection Frequency	7
Notes	Submerged aquatic vegetation in 0-3 ft water; creek productive for spotted seatrout

SHA #14	New River - Western Stones Bay
Description	Mouth of Muddy Creek, mouth of Stone's Creek, Stones Landing
Acres	570
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3, 3-6, and >6 ft, high salinity SAV, low-elevation uplands, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA, SSNA
Conservation Lands	Camp Lejeune (federal)
Water Quality Ratings	mostly impaired
Water Quality Classifications	HQW, SA
Fish Data	Core station nearby in Mill Creek
	shrimp
Prominent Alterations	drained wetlands, prohibited shellfish harvest, trawling (temporarily opened)
Average Total Alteration Score	1.70
Average Selection Frequency	15
Notes	Productive for spotted sea trout, red drum

SHA #15	New River - Northern Stones Bay
Description	Mouth of Mill Creek, Foys Landing to Catfish Point
Acres	570
Prominent Habitats	Estuarine soft bottom 0-3 ft, high salinity SAV, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA
Conservation Lands	Camp Lejeune (federal)
Water Quality Ratings	mostly supporting
Water Quality Classifications	HQW, SA
Fish Data	Core station nearby in Mill Creek
	shrimp
Prominent Alterations	drained wetlands, trawling (temporarily opened)
Average Total Alteration Score	2.21
Average Selection Frequency	9
Notes	Productive for spotted sea trout, red drum

SHA #21	New River - Southwest Creek
Description	flats, braided creek
Acres	1,050
Prominent Habitats	Emergent, shrub/scrub, and forested wetlands, estuarine soft bottom 3-6 ft, low-elevation uplands, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA, SNHA
Conservation Lands	Camp Lejeune (federal)
Water Quality Ratings	half impaired and half unknown
Water Quality Classifications	HQW, NSW
Fish Data	No
Prominent Alterations	drained wetlands, development, agriculture, prohibited shellfish harvest
Average Total Alteration Score	2.00
Average Selection Frequency	6
Notes	SNHA - Camp Lejeune Southwest Creek, owned by USDOD, C rating = moderate, R rating = outstanding; productive for red drum and spotted sea trout

SHA #30	New River - Northeast Creek
Description	Upper half of Northeast Creek and most of Little Northeast Creek
Acres	810
Prominent Habitats	Forested and shrub/scrub wetlands, low-elevation uplands, wetland edge, streams (low elevation)
Ecological Designations	AFSA, SNHA
Conservation Lands	Northeast Creek Park (municipal)
Water Quality Ratings	unknown
Water Quality Classifications	NSW
Fish Data	Core station downstream in PNA none
Prominent Alterations	bridge constriction, drained wetlands, minor NPDES, mines, development, prohibited shellfish harvest
Average Total Alteration Score	2
Average Selection Frequency	6
Notes	SNHA - Northeast Creek Tidal Forests, privately owned, C rating = moderate, R rating = high; wide forested wetlands protects from shoreline development; productive for red drum and spotted sea trout

SHA #36	Upper New River
Description	Upper New River northeast of Jacksonville
Acres	2,010
Prominent Habitats	Forested and shrub/scrub wetlands, wetland edge, streams (low elevation)
Ecological Designations	AFSA, SNHA
Conservation Lands	New River Swamps and Marshes (TNC) Preserve (private), Oakhurst Nature Park (local)
Water Quality Ratings	mostly not rated and some impaired
Water Quality Classifications	NSW
Fish Data	Core station just downstream - spot
Prominent Alterations	minor NPDES, animal operations, development, agriculture, prohibited shellfish harvest
Average Total Alteration Score	1.55
Average Selection Frequency	52
Notes	SNHA - New River Swamps and Marshes, owned by private, TNC, and local government, C rating = general, R rating = general

White Oak River and Onslow waters

SHA #18	Bear Inlet
Description	Bear Inlet, Sanders Island, Sanders Creek, ICW, Bear Creek, lower Mill Creek, and shores of western Bear Island
Acres	3,450
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 ft, intertidal shell bottom, marine soft bottom 0-3 ft, wetland edge
Ecological Designations	PNA, SNHA
Conservation Lands	Camp Lejeune (federal), Hammocks Beach (state)
Water Quality Ratings	half impaired and half supporting
Water Quality Classifications	ORW, HQW, SA
Fish Data	No
Prominent Alterations	dredged channels, drained wetlands, docks and bridges, some prohibited shellfish harvest, trawling (permanently open)
Average Total Alteration Score	0.66
Average Selection Frequency	327
Notes	SNHA - Camp Lejeune Browns Island, owned by USDOD, C rating = moderate, R rating = very high; SNHA - Hammocks Beach State Park, owned by NCDPR, C rating = outstanding, R rating = outstanding; open to shellfish harvest except upper half of Bear Creek

SHA #20	Queen Creek
Description	Lower Queen Creek near Parrot Swamp
Acres	360
Prominent Habitats	Emergent wetlands, intertidal and subtidal shell bottom, wetland edge
Ecological Designations	PNA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	No
Prominent Alterations	minor NPDES, mines, development, agriculture, some prohibited shellfish harvest
Average Total Alteration Score	2.93
Average Selection Frequency	106
Notes	Lower half of Queen's Creek open to shellfish harvest; low development

SHA #25	Bogue Inlet
Description	Bogue Inlet, Dudley Island, Cow Channel, Banks Channel, Burden Channel, Huggins Island, Jones Island, Mouth of Pettiford Creek Bay, and the lower White Oak River up to just north of Cahoon Point
Acres	10,440
Prominent Habitats	Emergent wetlands, estuarine 0-3 ft, high salinity SAV, non-wetland edge, wetland edge
Ecological Designations	SNHA
Conservation Lands	Hammocks Beach State Park (State), Emerald Isle Woods Park (local), Jones Island Audubon Sanctuary (privately), Croatan National Forest (federal)
Water Quality Ratings	half impaired and half supporting
Water Quality Classifications	ORW, HQW, SA
Fish Data	pgm 120, spot
Prominent Alterations	bulkheads, canals, dredged channels, drained wetlands, minor NPDES, marinas, development, agriculture, docks and bridges, some prohibited shellfish harvest but mostly open, trawling (permanently and temporarily open), mechanical clam harvest area
Average Total Alteration Score	1.77
Average Selection Frequency	238
Notes	Productive shellfish, trout, abundant seagrass in sound; productive shrimp and shellfish; SNHA - Hammocks Beach State Park, Huggins/Dudley Island, mostly owned by NCDPR,; SNHA - Emerald Isle/West End Beach, privately owned; SNHA - Emerald Isle Woods, owned by local government; SNHA - Bogue Inlet/Bogue Sound Bird Nesting Islands, owned by USDOD, and some areas privately owned; SNHA - Jones Island, owned by NCDPR and some areas privately owned; SNHA - White Oak River Marshes, owned by USFS

SHA #32	Middle White Oak River
Description	Where the White Oak River narrows just south of Stella
Acres	570
Prominent Habitats	Emergent and shrub/scrub wetlands, wetland edge, streams (low elevation)
Ecological Designations	PNA, AFSA
Conservation Lands	White Oak River Game Land (state)
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	pgm 120 (CORE)
	low catches
Prominent Alterations	impoundments, bridge constriction, ditching, drained wetlands, agriculture, prohibited shellfish harvest
Average Total Alteration Score	3.39
Average Selection Frequency	224
Notes	Croatan Wildlife Refuge in watershed

SHA #38	Upper White Oak River
Description	Upper portion of White Oak River from near the mouth of Hunters Creek and Freemans Creek upstream to mouth of Mulberry Creek just downstream of Haywood Landing
Acres	1,590
Prominent Habitats	Emergent, shrub/scrub, and forested wetlands, riverine soft bottom (ND), wetland edge, streams (low elevation)
Ecological Designations	PNA, AFSA, SNHA
Conservation Lands	Croatan National Forest (federal), White Oak River Game Land (state)
Water Quality Ratings	mostly supporting or unknown
Water Quality Classifications	HQW
Fish Data	No
Prominent Alterations	bridge constrictions, ditching, drained wetlands, agriculture, prohibited shellfish harvest
Average Total Alteration Score	3.36
Average Selection Frequency	123
Notes	SNHA - White Oak River Marshes and Swamps, owned by USFS, NCWRC, and some areas privately owned

Bogue Sound Area

SHA #19	Hard bottom off Emerald Isle (4.1 nmi E of Bogue Inlet)
Description	Likely natural hard bottom
Acres	630
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	SNHA
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Reliability = 9/15, relief unknown, SNHA - Bogue Inlet Outcrop

SHA #16	Hard bottom off Emerald Isle (5.0 nmi ESE of Bogue Inlet)
Description	Likely natural hard bottom
Acres	60
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Reliability = 14/15, relief unknown

SHA #22	Western Bogue Sound
Description	Mouth of Archer Creek, Piney Island, Long Marsh, and Lovett Island
Acres	1,350
Prominent Habitats	Emergent wetlands, estuarine soft bottom 3-6 ft, high salinity SAV, wetland edge
Ecological Designations	PNA, SNHA
Conservation Lands	None
Water Quality Ratings	mostly supporting
Water Quality Classifications	ORW, SA
Fish Data	pgm 120
	spot and shrimp
Prominent Alterations	drained wetlands, development, docks and bridges
Average Total Alteration Score	0.90
Average Selection Frequency	168
Notes	Seagrass, productive for shrimp; sound open to shellfish harvest; SNHA - Bogue Inlet/Bogue Sound Bird Nesting Islands, owned by USDOD, NAS, and some areas privately owned

SHA #46	Broad Creek
Description	Tidal creek off Bogue Sound
Acres	330
Prominent Habitats	Marsh and forested wetlands; some submerged aquatic vegetation
Ecological Designations	PNA
Conservation Lands	
Water Quality Ratings	impaired
Water Quality Classifications	HQW; closed to shellfish harvest
Fish Data	Blue crab;
Prominent Alterations	Closed to shellfish harvest; partial obstruction at mouth (causeway/bridge); channelized branch in upper reaches, docks
Average Total Alteration Score	2.53
Average Selection Frequency	47
Notes	

SHA #47	Gales Creek
Description	Tidal creek off Bogue Sound
Acres	180
Prominent Habitats	Marsh and forested wetlands; some submerged aquatic vegetation
Ecological Designations	PNA
Conservation Lands	
Water Quality Ratings	impaired
Water Quality Classifications	HQW, closed to shellfish harvest
Fish Data	Blue crab, southern flounder
Prominent Alterations	Closed to shellfish harvest; partial obstruction at mouth (causeway/bridge)
Average Total Alteration Score	2.88
Average Selection Frequency	46
Notes	

SHA #44	Roosevelt Natural Area, Pine Knoll Shores
Description	Undeveloped property surrounding NC Aquarium (part of Theodore Roosevelt Natural Area)
Acres	270
Prominent Habitats	Extensive marsh, forested wetlands, submerged aquatic vegetation, low elevation uplands
Ecological Designations	PNA, SNHA – high value
Conservation Lands	T. Roosevelt Natural Areas, NC Aquarium
Water Quality Ratings	supporting
Water Quality Classifications	ORW, open shellfish harvest, SNHA – high rating
Fish Data	No sampling data
Prominent Alterations	Minimal development
Average Total Alteration Score	1.9
Average Selection Frequency	7
Notes	

SHA #45	Hoop Pole Creek (Atlantic Beach)
Description	Creek and adjacent habitats
Acres	960
Prominent Habitats	Extensive submerged aquatic vegetation, marsh, tidal creeks, some intertidal shell
Ecological Designations	SNHA – moderate rating
Conservation Lands	
Water Quality Ratings	mostly supporting
Water Quality Classifications	HQW,
Fish Data	Spot, blue crab
Prominent Alterations	Adjacent development, docks
Average Total Alteration Score	1.84
Average Selection Frequency	28
Notes	

Newport River

SHA #26	Lower Newport River near HWY 70
Description	Marsh area in Newport River near Town Creek, adjacent to HWY 70 between Beaufort Channel, Phillips Island, and Gallant Channel
Acres	330
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 ft and >6 ft, high salinity SAV, intertidal and subtidal shell bottom, wetland edge, streams (low elevation)
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	No
Prominent Alterations	development, trawling (permanently open)
Average Total Alteration Score	1.36
Average Selection Frequency	254
Notes	

SHA #27	Calico Creek and Crab Point Bay (Morehead City)
Description	Areas near Morehead City including mouth of Calico Creek, mouth of Crab Point Bay, Willis Creek, and Willis Point
Acres	450
Prominent Habitats	Emergent wetlands, Estuarine soft bottom 0-3 ft, intertidal shell bottom, subtidal shell bottom, low-elevation uplands, wetland edge
Ecological Designations	PNA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	3 stations nearby
	spot
Prominent Alterations	drained, riprap, major NPDES, development, docks and bridges, prohibited shellfish harvest, trawling (permanently open)
Average Total Alteration Score	3.34
Average Selection Frequency	138
Notes	

SHA #31	Newport Marshes
Description	Newport Marshes in the mouth of the Newport River, including marshes near Crab Point
Acres	1,110
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 and >6 ft, wetland edge, streams (low elevation)
Ecological Designations	SNHA
Conservation Lands	Hay Stack Marsh Preserver (Land Trust)
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	One station nearby
	spot
Prominent Alterations	drained wetlands, riprap, development, trawling (permanently open), mechanical clam harvest area
Average Total Alteration Score	1.43
Average Selection Frequency	128
Notes	SNHA - Phillips and Annex Islands, (private); rating = moderate and high

SHA #33	Upper Newport River
Description	Newport River from near Oyster Point, Cross Rock, Lawton Point, Penn Point, Turtle Rock, White Rock, mouth of Harlowe Creek, to just west of Oyster Creek
Acres	2,640
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 and 3-6 ft, subtidal shell bottom, wetland edge, streams (low elevation)
Ecological Designations	PNA, SSNA
Conservation Lands	Croatan National Forest (federal)
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	Core station on border Low catches of priority species
Prominent Alterations	drained wetlands, development, docks and bridges, prohibited shellfish harvest
Average Total Alteration Score	1.04
Average Selection Frequency	264
Notes	

North River/Back Sound

SHA #23	Carrot Island
Description	Middle section of Carrot Island
Acres	510
Prominent Habitats	Emergent and shrub/scrub wetlands, Estuarine 0-3 ft, intertidal and subtidal shell bottom, low-elevation uplands, wetland edge
Ecological Designations	SNHA
Conservation Lands	Rachel Carson Estuarine Reserve (state)
Water Quality Ratings	mostly impaired
Water Quality Classifications	HQW, SA
Fish Data	No
Prominent Alterations	major NPDES, minor NPDES, development, trawling (permanently open)
Average Total Alteration Score	2.58
Average Selection Frequency	118
Notes	SNHA - Rachel Carson Estuarine Research Reserve, owned by NCDCM, C rating = very high, R rating = very high

SHA #24	Beaufort Inlet
Description	Beaufort Inlet, main channel between Radio Island and Fort Macon, and area between Bird Shoal and Shackleford Banks
Acres	2,220
Prominent Habitats	Estuarine soft bottom 0-3, 3-6, and >6 ft, marine soft bottom >6 ft, non-wetland edge, wetland edge
Ecological Designations	SNHA
Conservation Lands	Rachel Carson Estuarine Reserve (state); Cape Lookout National Seashore - Shackleford Banks Wilderness (federal)
Water Quality Ratings	mostly supporting
Water Quality Classifications	ORW, HQW, SA
Fish Data	No
Prominent Alterations	dredged channels, major NPDES, minor NPDES, development, trawling (permanently open)
Average Total Alteration Score	1.65
Average Selection Frequency	2
Notes	SNHA - Fort Macon State Park/Brandt Island, owned by NCPA, NCDPR, C rating = very high, R rating = outstanding; SNHA = Shackleford Banks, owned by USNPS, rating = outstanding and very high

SHA #28	Middle Marshes
Description	Middle marshes, Sheephead Marsh, and North River Marsh to the mouth of Gibbs Creek
Acres	2,700
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3, 3-6, and >6 ft, intertidal shell bottom, wetland edge
Ecological Designations	SNHA
Conservation Lands	Rachel Carson Estuarine Reserve (state)
Water Quality Ratings	mostly impaired
Water Quality Classifications	ORW, HQW, SA
Fish Data	No
Prominent Alterations	minor NPDES, development, trawling (permanently open)
Average Total Alteration Score	1.62
Average Selection Frequency	259
Notes	SNHA - Rachel Carson Estuarine Research Reserve, owned by NCDCM, C rating = very high, R rating = very high

SHA #35	Lower North River
Description	Lower North River west of Thomas Creek and South of the HWY 70 bridge
Acres	300
Prominent Habitats	Estuarine 0-3 ft, subtidal shell bottom, wetland edge
Ecological Designations	SSNA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	Core station just north
	Low catches of priority species
Prominent Alterations	mechanical clam harvest area
Average Total Alteration Score	0.67
Average Selection Frequency	233
Notes	

SHA #37	Ward Creek
Description	Includes the Ward Creek area from the mouth to where the channel narrows
Acres	510
Prominent Habitats	Emergent and shrub/scrub wetlands, estuarine soft bottom 0-3 ft, subtidal shell bottom, non-wetland edge, wetland edge
Ecological Designations	PNA, SSNA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	pgm 120
	shrimp
Prominent Alterations	bridge constrictions, drained wetlands, agriculture, docks and bridges, prohibited shellfish harvest
Average Total Alteration Score	2.42
Average Selection Frequency	131
Notes	

SHA #39	Upper North River
Description	Upper North River from just north of Crabbing Creek west to the mouth of Deep Creek and north to where the channel narrows
Acres	390
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 ft, subtidal shell bottom, wetland edge, streams (low elevation)
Ecological Designations	PNA, SNHA
Conservation Lands	North River (NCCF) Preserve (private)
Water Quality Ratings	impaired
Water Quality Classifications	HQW, SA
Fish Data	Core station adjacent upstream Low catches of priority species
Prominent Alterations	bridge constrictions, drained wetlands, agriculture, some prohibited shellfish harvest
Average Total Alteration Score	2.76
Average Selection Frequency	48
Notes	SNHA – North River Brackish Marshes, owned by NCCF and some areas privately owned, C rating = moderate, R rating = high

Core Sound Area

SHA #13	Ocean hard bottom (3.7 nmi WSW of Cape Lookout)
Description	Likely natural hard bottom
Acres	53
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Confirmed as a rock ledge by divers (see NOAA Obstructions Data)

SHA #17	Artificial reef off Core Banks (2.5 nmi NW of Cape Lookout)
Description	Obstruction, not natural hard bottom
Acres	150
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Obstruction on NOAA chart

SHA #12	Artificial reef off Core Banks (3.0 nmi S of Cape Lookout)
Description	Wreck and possible obstruction, not natural hard bottom
Acres	180
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	N/A
Water Quality Ratings	N/A
Water Quality Classifications	N/A
Fish Data	No
Prominent Alterations	trawling (permanently open)
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Obstruction (in western half – not proven) and wreck

SHA #29	The Straits
Description	The Straits north of Harkers Island and Browns Island from the edge of Lovls Shore and Horse Marsh west to Sleepy Creek including the mouth of Whitehurst Creek
Acres	1,650
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3, 3-6, and >6 ft, high salinity SAV, SAV and shell bottom, subtidal shell bottom, non-wetland edge, wetland edge
Ecological Designations	PNA, SNHA
Conservation Lands	None
Water Quality Ratings	mostly supporting
Water Quality Classifications	HQW, SA
Fish Data	pgm 120
	blue crabs, spot, and shrimp
Prominent Alterations	bulkheads, canals and boat basins, drained, riprap, docks and bridges, trawling (permanently open)
Average Total Alteration Score	1.37
Average Selection Frequency	176
Notes	SNHA – Browns Island, privately owned, C rating = moderate, R rating = high

SHA #34	Jarrett Bay
Description	Lower Jarrett Bay, Spit Bay, mouth of Wade Creek, Middens Creek, Davis Island, south to the mouth of Tusk Creek
Acres	2,400
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-6 and 3-6 ft, high salinity SAV, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	PNA, AFSA
Conservation Lands	None
Water Quality Ratings	impaired
Water Quality Classifications	ORW, HQW, SA
Fish Data	pgm 120
	shrimp
Prominent Alterations	drained wetlands, mines, agriculture, docks and bridges, trawling (temporarily open), mechanical clam harvest area
Average Total Alteration Score	2.38
Average Selection Frequency	43
Notes	

SHA #40	Lola, Cedar Island Bay
Description	Cedar Island National Wildlife Refuge between Lewis Creek and Island Bay to HWY 12
Acres	1,408
Prominent Habitats	Emergent, shrub/scrub, and forested wetlands, estuarine soft bottom 0-3 ft, non-wetland edge, wetland edge, streams (low elevation)
Ecological Designations	SNHA
Conservation Lands	Cedar Island National Wildlife Refuge (federal)
Water Quality Ratings	supporting
Water Quality Classifications	ORW, HQW, SA, NSW
Fish Data	Core station in adjacent creek
	Blue crabs, spot, and shrimp
Prominent Alterations	riprap
Average Total Alteration Score	0.87
Average Selection Frequency	108
Notes	SNHA - Cedar Island Flatwoods and Bays, owned by USFWS, C rating = high, R rating = high

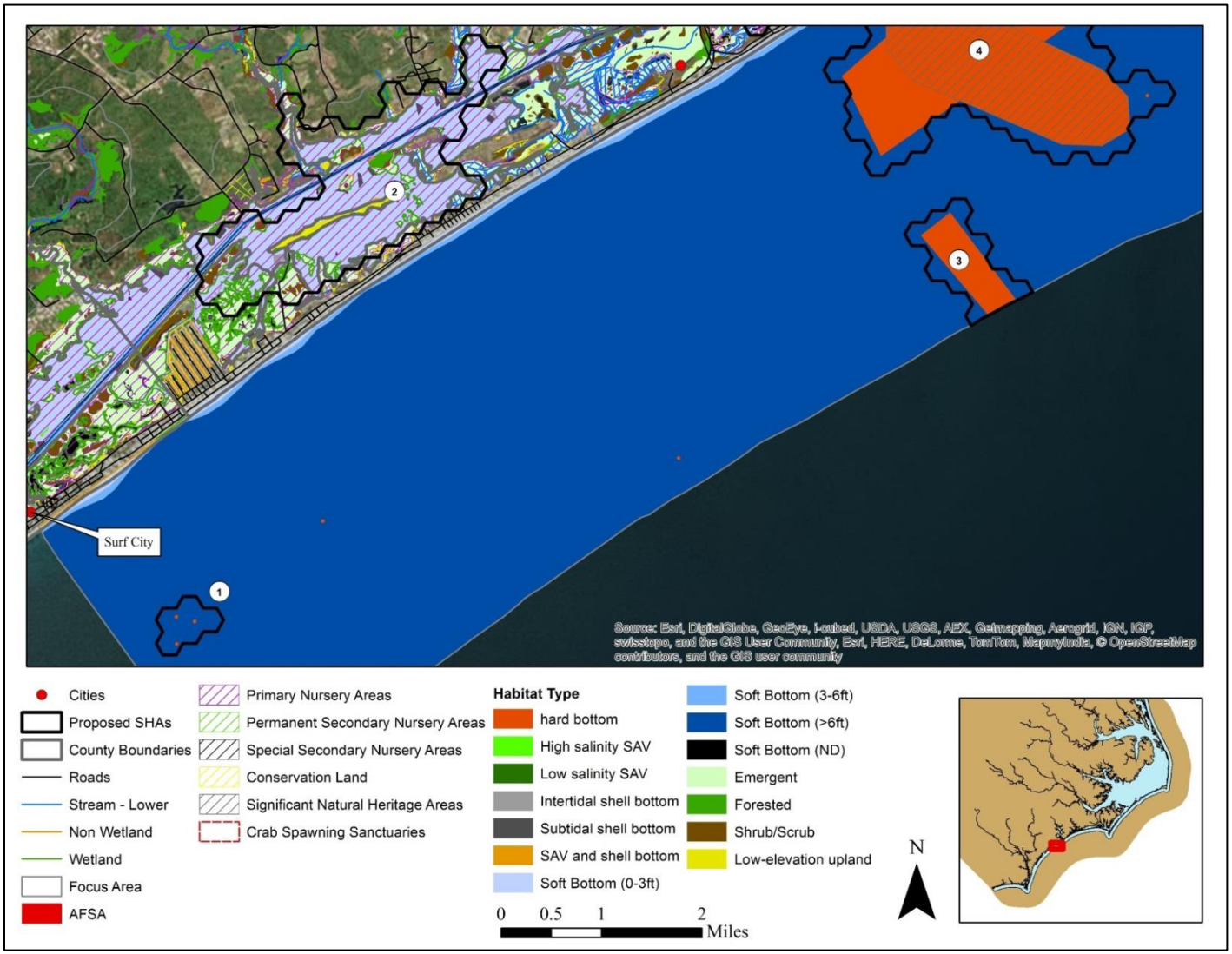
SHA #41	Cedar Island and Back bays near Hog Island
Description	Northeast part of Cedar Island including Hog Island, nearby marshes, and Back Bay
Acres	2,915
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3 and 3-6 ft, high salinity SAV, non-wetland edge, wetland edge
Ecological Designations	PNA, SSNA, SNHA
Conservation Lands	None
Water Quality Ratings	supporting
Water Quality Classifications	ORW, SA, NSW
Fish Data	pgm 120
	low catches of priority species
Prominent Alterations	trawling (temporarily open)
Average Total Alteration Score	0.51
Average Selection Frequency	196
Notes	SNHA - Cedar Island/North Bay Barrier Strand, owned by USFWS and some areas are privately owned, C rating = high, R rating = high

SHA #42	Hard bottom off Ocracoke (3.3 nmi SW of Ocracoke Inlet)
Description	Wrecks, not natural hard bottom
Acres	90
Prominent Habitats	Hard bottom and marine soft bottom >6ft
Ecological Designations	None
Conservation Lands	None
Water Quality Ratings	N/A
Water Quality Classifications	NSW
Fish Data	No
Prominent Alterations	none
Average Total Alteration Score	N/A
Average Selection Frequency	N/A
Notes	Wreck of the trawler "ALBATROSS", Wreck of the "MIDGETT".

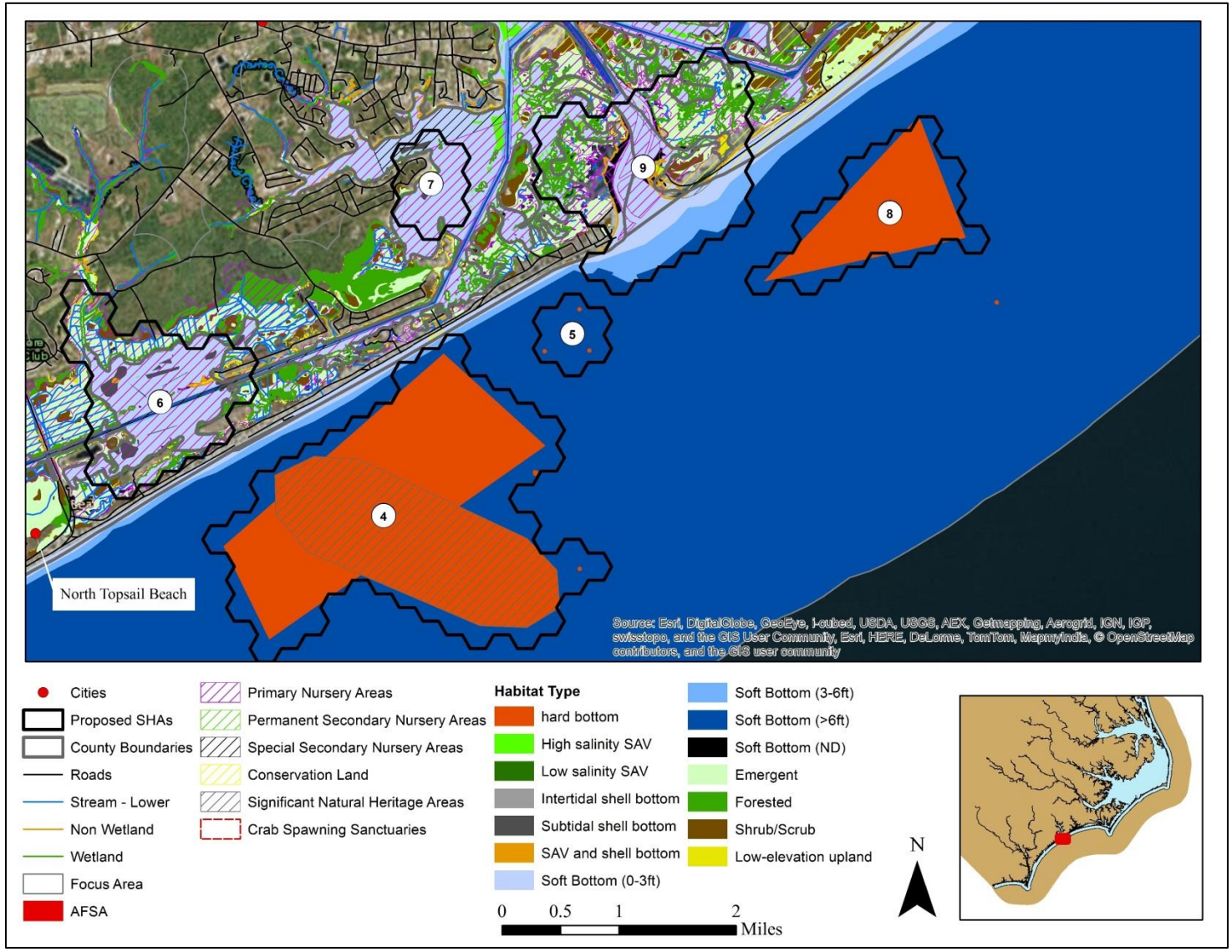
SHA #43	Core Sound
Description	Includes SAV and nearby marsh and waters behind Core Banks from Ocracoke Inlet southwest to Cape Lookout including eastern portions of Back Sound and Shackleford Banks, also includes New Drum Inlet and Ophelia Inlet
Acres	86,504
Prominent Habitats	Emergent wetlands, estuarine soft bottom 0-3, 3-6, and >6 ft, high salinity SAV, non-wetland edge, wetland edge
Ecological Designations	SNHA, Crab spawning sanctuary
Conservation Lands	Cape Lookout National Seashore - Shackleford Banks Wilderness (federal); Cape Hatteras National Seashore (federal)
Water Quality Ratings	supporting
Water Quality Classifications	ORW, HQW, SA, NSW
Fish Data	pgm 120 (CORE) low catches of priority species
Prominent Alterations	mechanical clam harvest area
Average Total Alteration Score	0.11
Average Selection Frequency	358
Notes	SNHA = Shackleford Banks, owned by USNPS, rating = outstanding and very high; SHNA - Core Banks and Portsmouth Island, owned by USNPS and some areas are privately owned, rating = outstanding; SNHA - Core Sound (Wainwright) Bird Nesting Islands, owned by NAS and some areas privately owned, rating = moderate and high; SNHA - Ocracoke Inlet Bird Nesting Islands, owned by NAS and NCWRC, rating = moderate and high; SNHA - Ocracoke Island Western End (Sand Flats), owned by USNPS, rating = very high and outstanding

SHA #48	Upper Thoroughfare Bay
Description	Includes Upper Thoroughfare Bay and Merkle Hammock Creek, excludes the Thoroughfare channel.
Acres	269
Prominent Habitats	High salinity SAV, low-elevation upland, wetland edge, emergent wetlands, estuarine soft bottom- all depths
Ecological Designations	PNA, SSNA
Conservation Lands	Cedar Island National Wildlife Refuge
Water Quality Ratings	Supporting; impaired for shellfish harvest (conditionally approved open)
Water Quality Classifications	ORW, HQW, SA
Fish Data	Pgm 120 (CORE) – high blue crab numbers
Prominent Alterations	Shrimp trawling
Average Total Alteration Score	0.87
Average Selection Frequency	108
Notes	SNHA = Cedar Island Wildlife Refuge

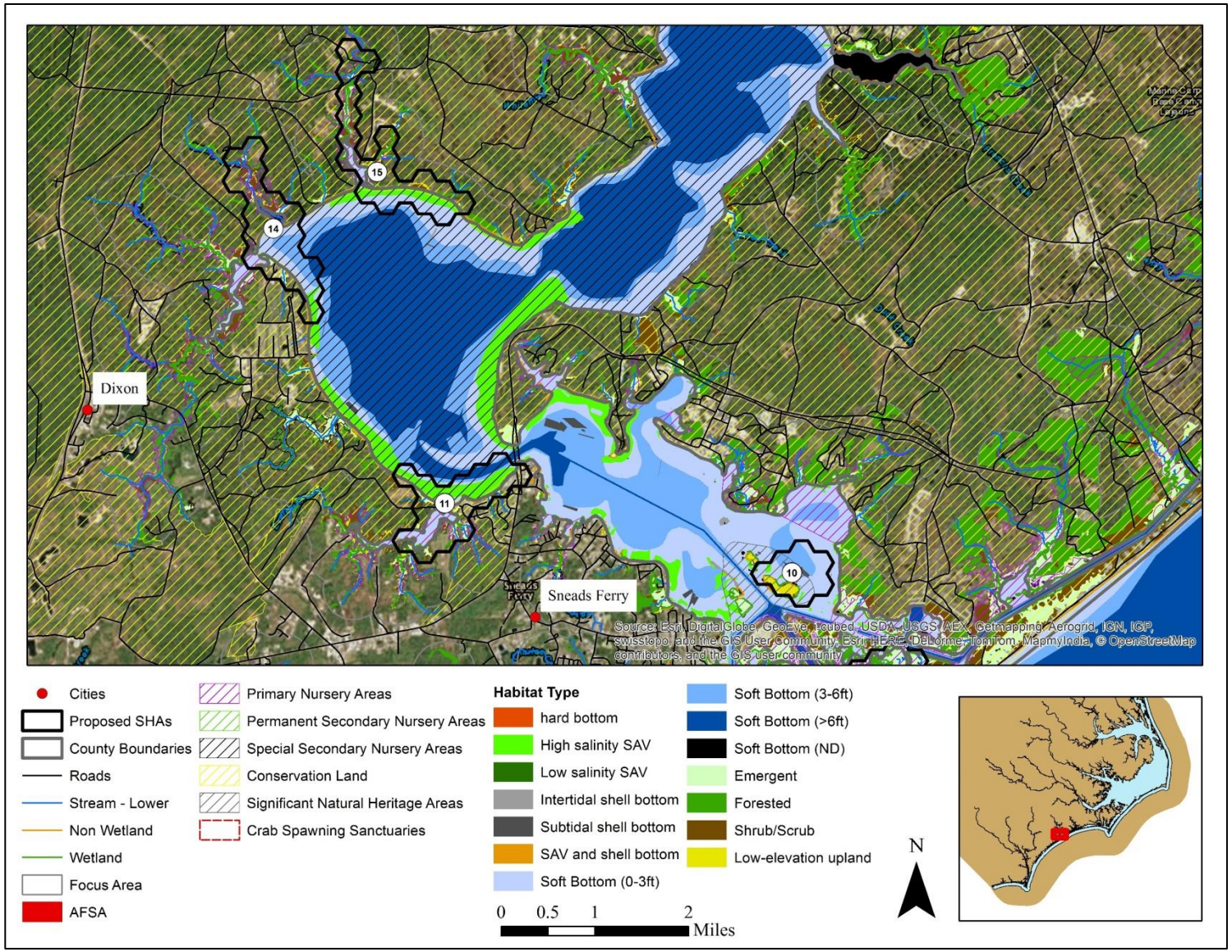
MAPS OF FINAL INDIVIDUAL SHA UNITS



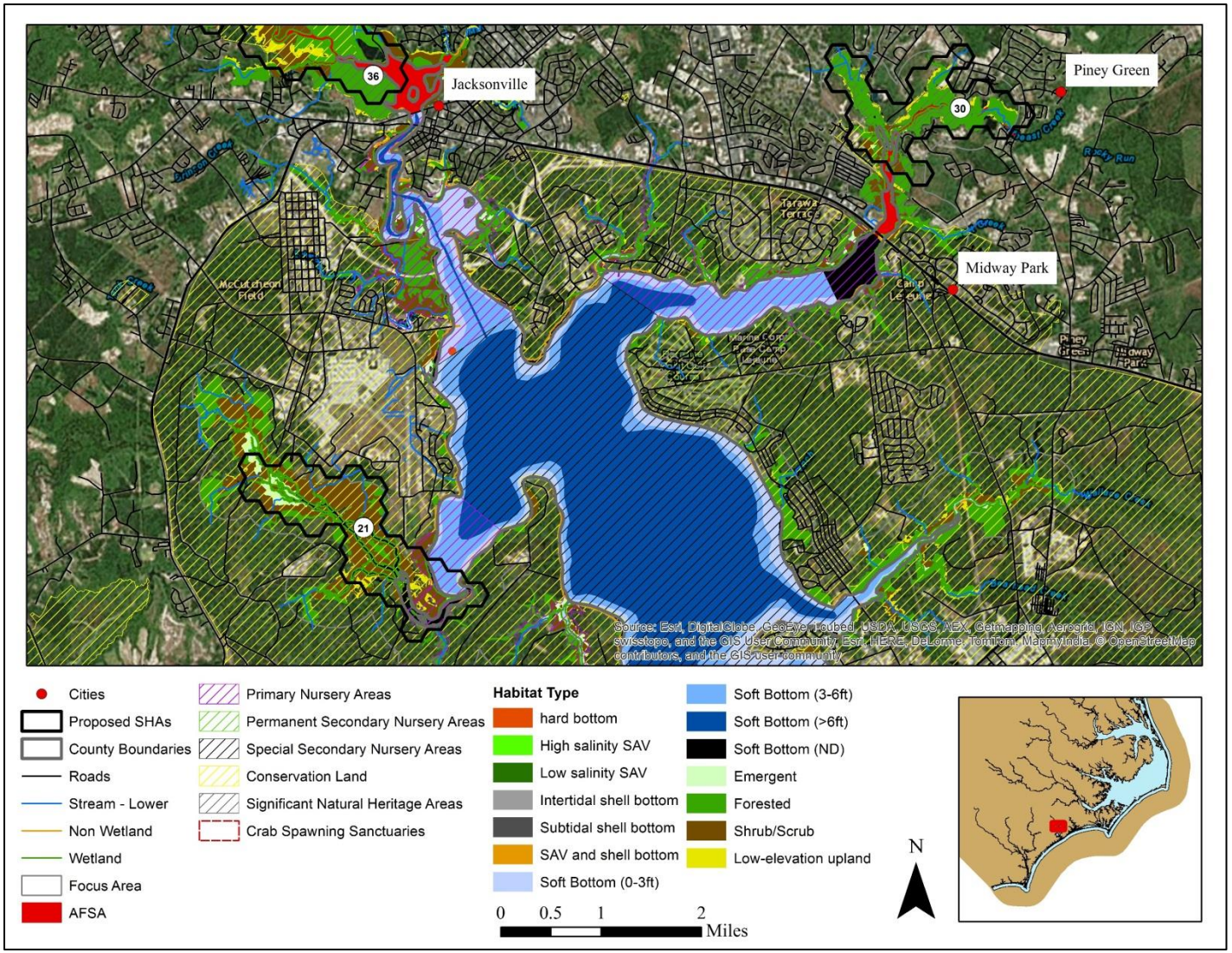
Map 12. Draft SHA nominations, Stump Sound, King's Creek, Atlantic Ocean. Shows SHA # 1-4.



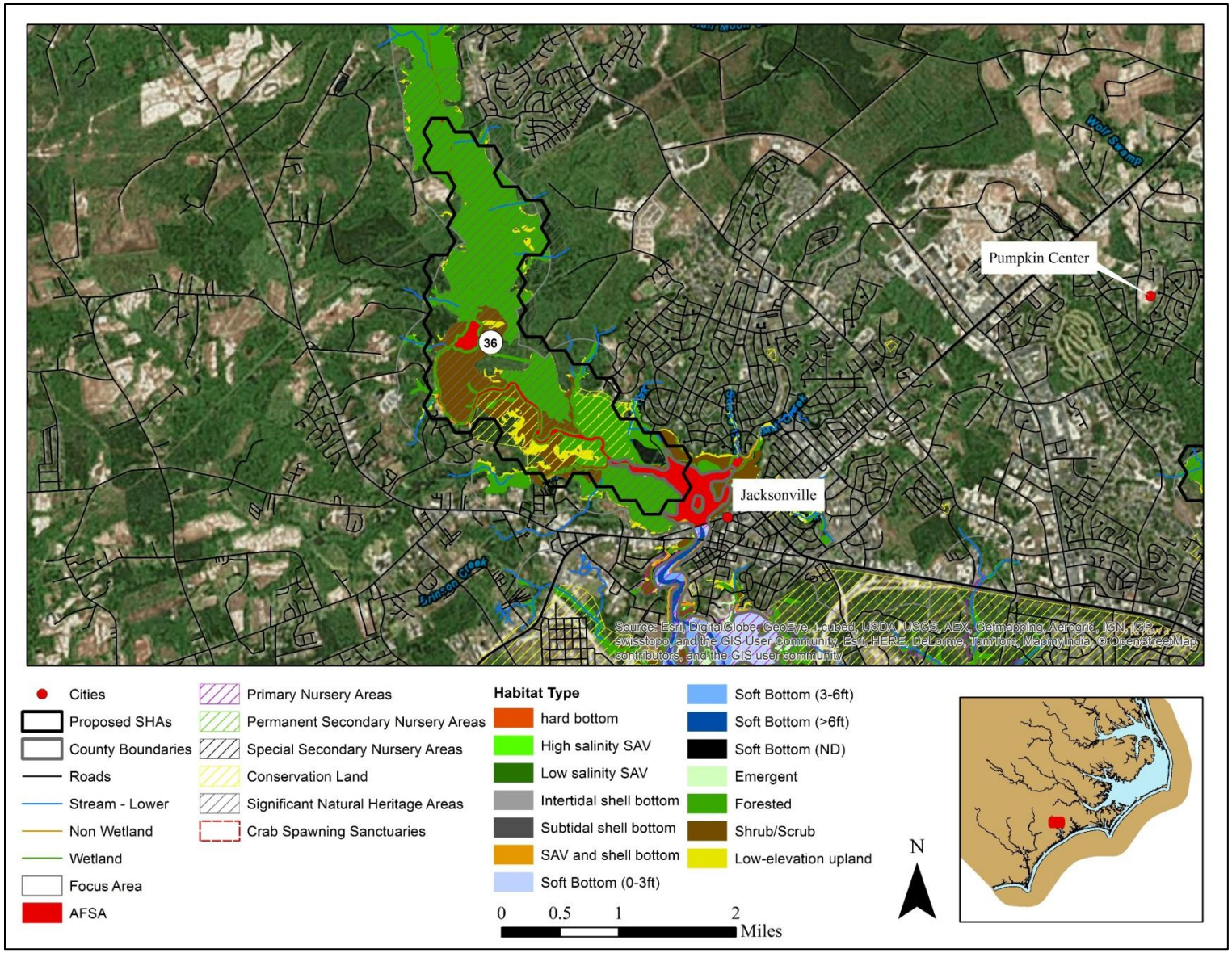
Map 13. Draft SHA nominations, Alligator and Chadwick bays, New River Inlet, and Atlantic Ocean. Shows SHA # 4-9.



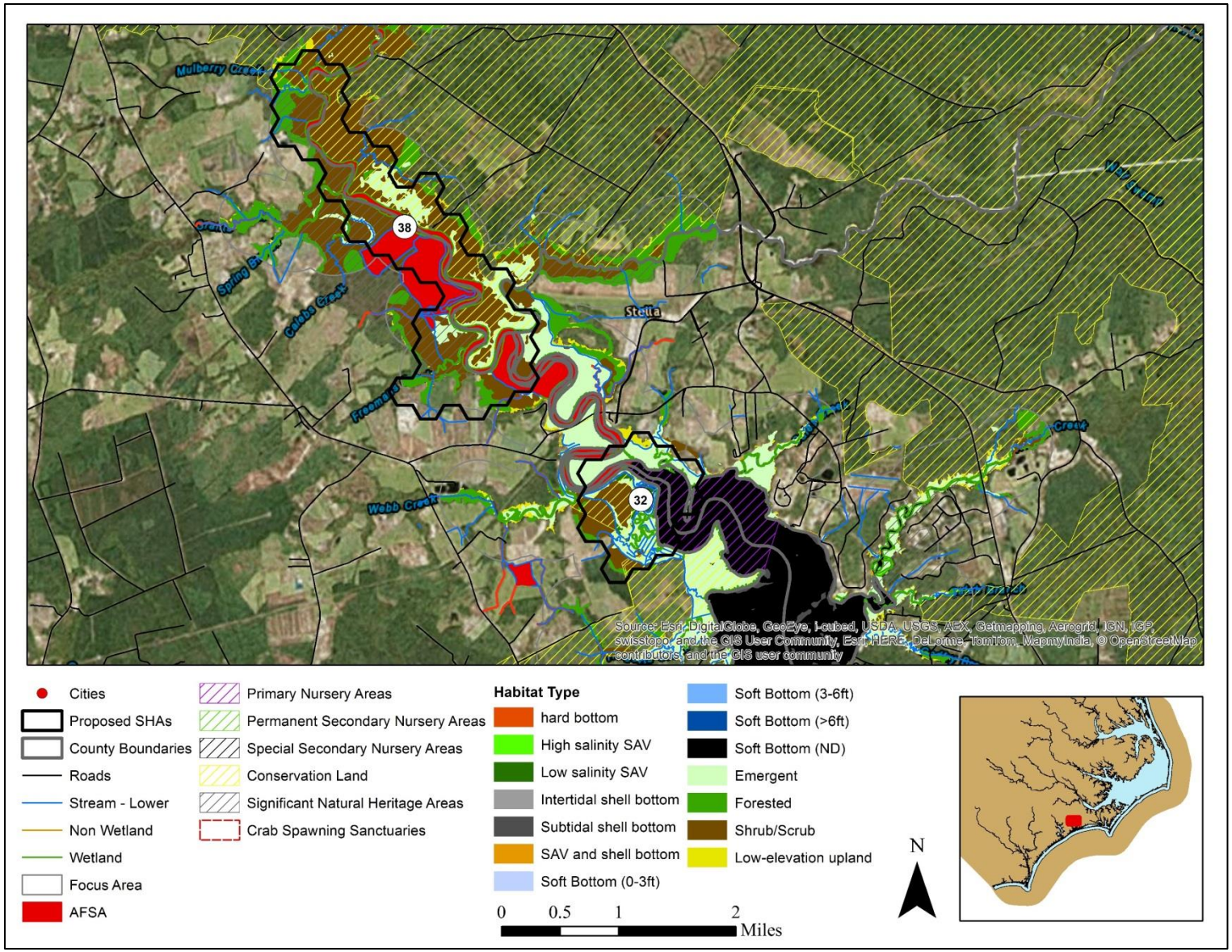
Map 14. Draft SHA nominations in New River. Shows SHA # 10, 11, 14, and 15.



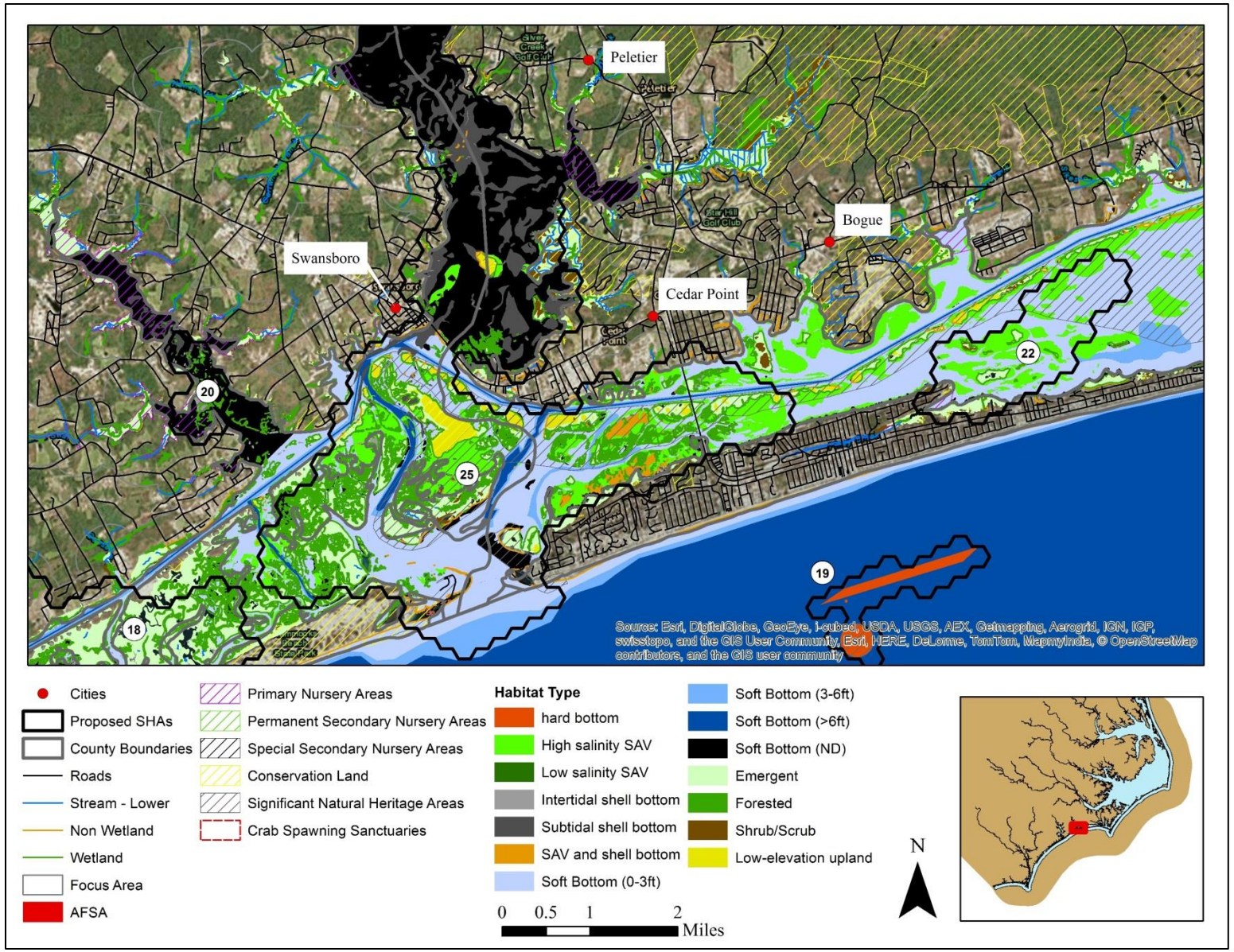
Map 15. Draft SHA nominations, Upper New River, Northeast and Southwest creeks. Shows SHA #21, 30, 36.



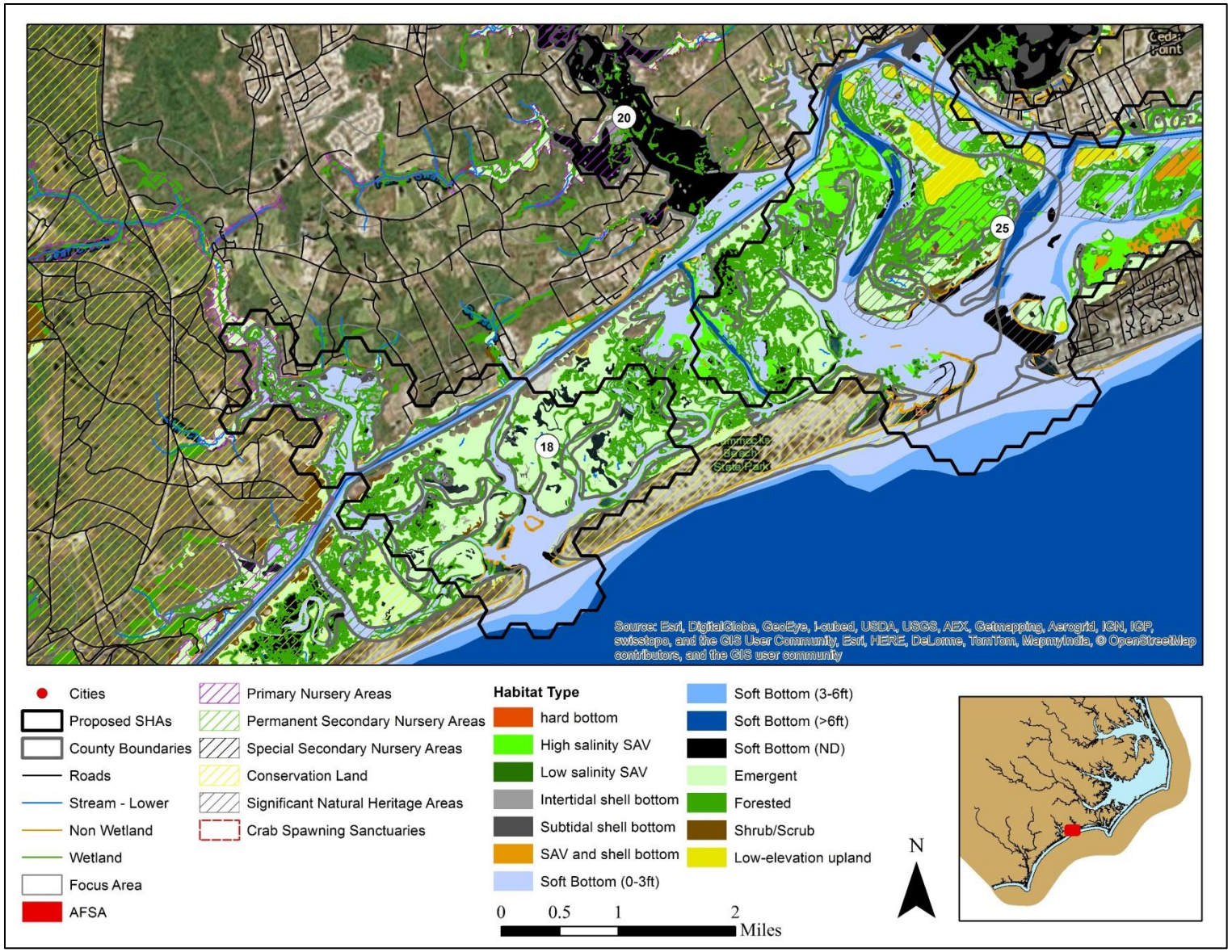
Map 16. Draft SHA nominations, Upper New River. Shows SHA # 36.



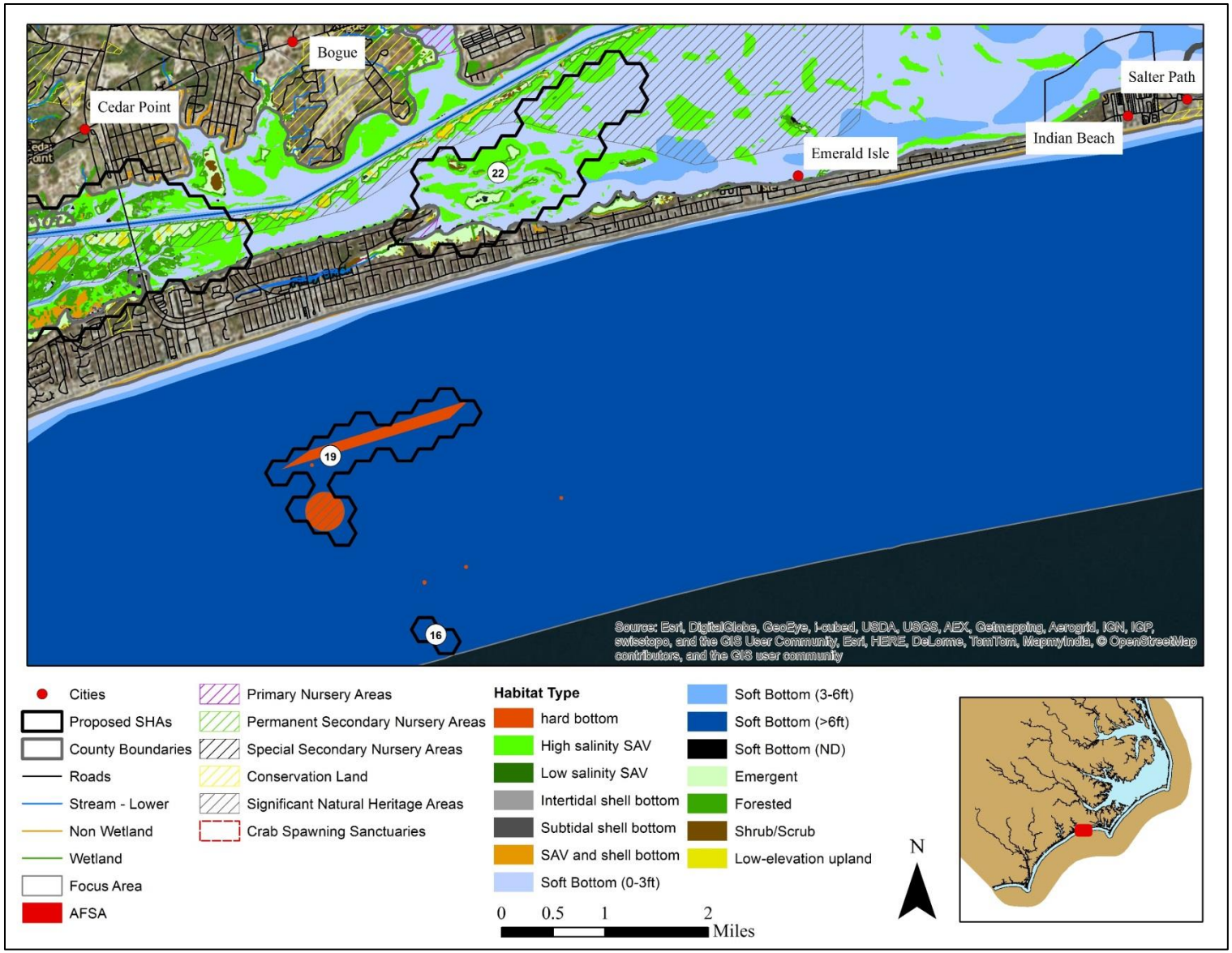
Map 17. Draft SHA nominations Upper White Oak River. Shows SHA # 32 and 38.



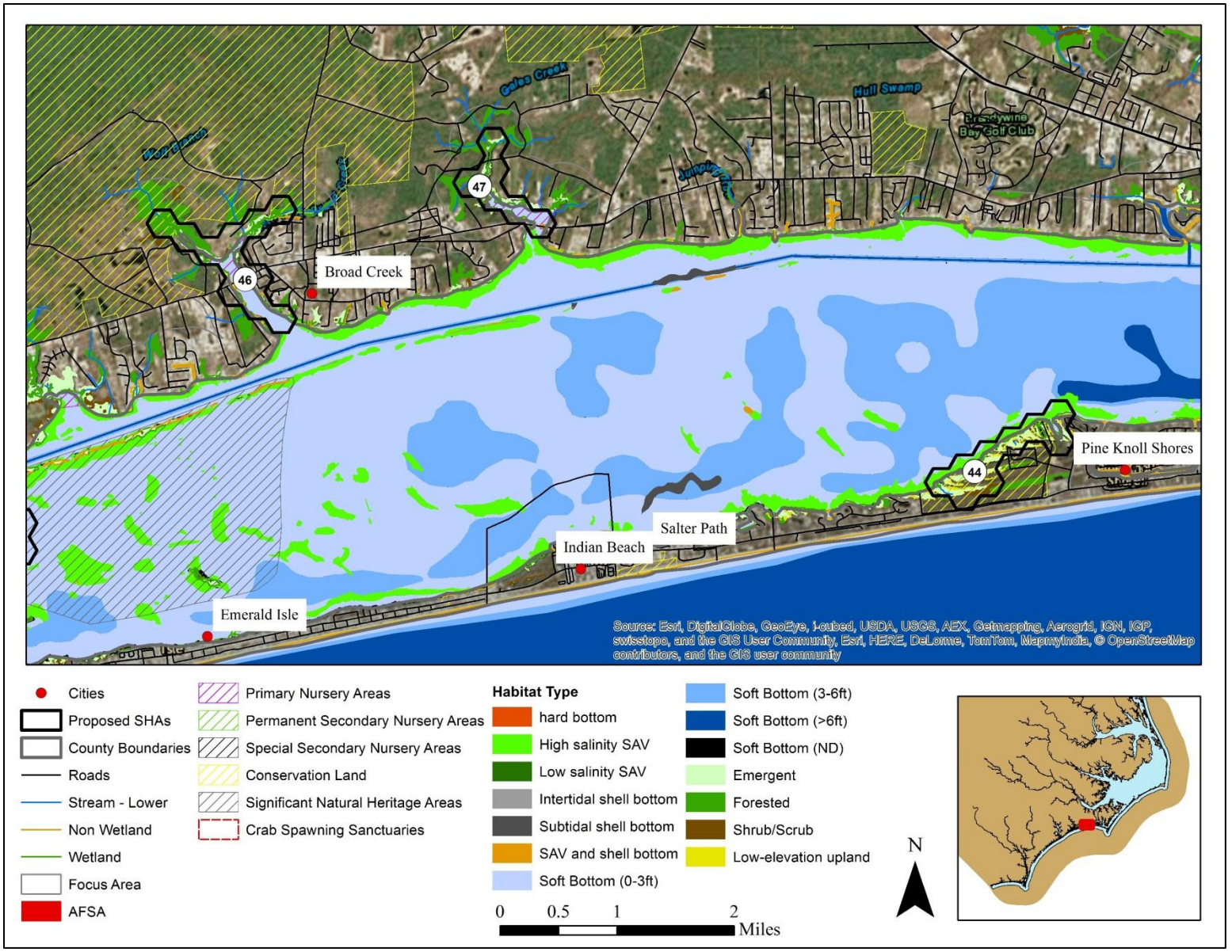
Map 18. Draft SHA nominations, lower White Oak River, Bogue Inlet, and western Bogue Sound. Shows SHA # 19, 20, 22, 25.



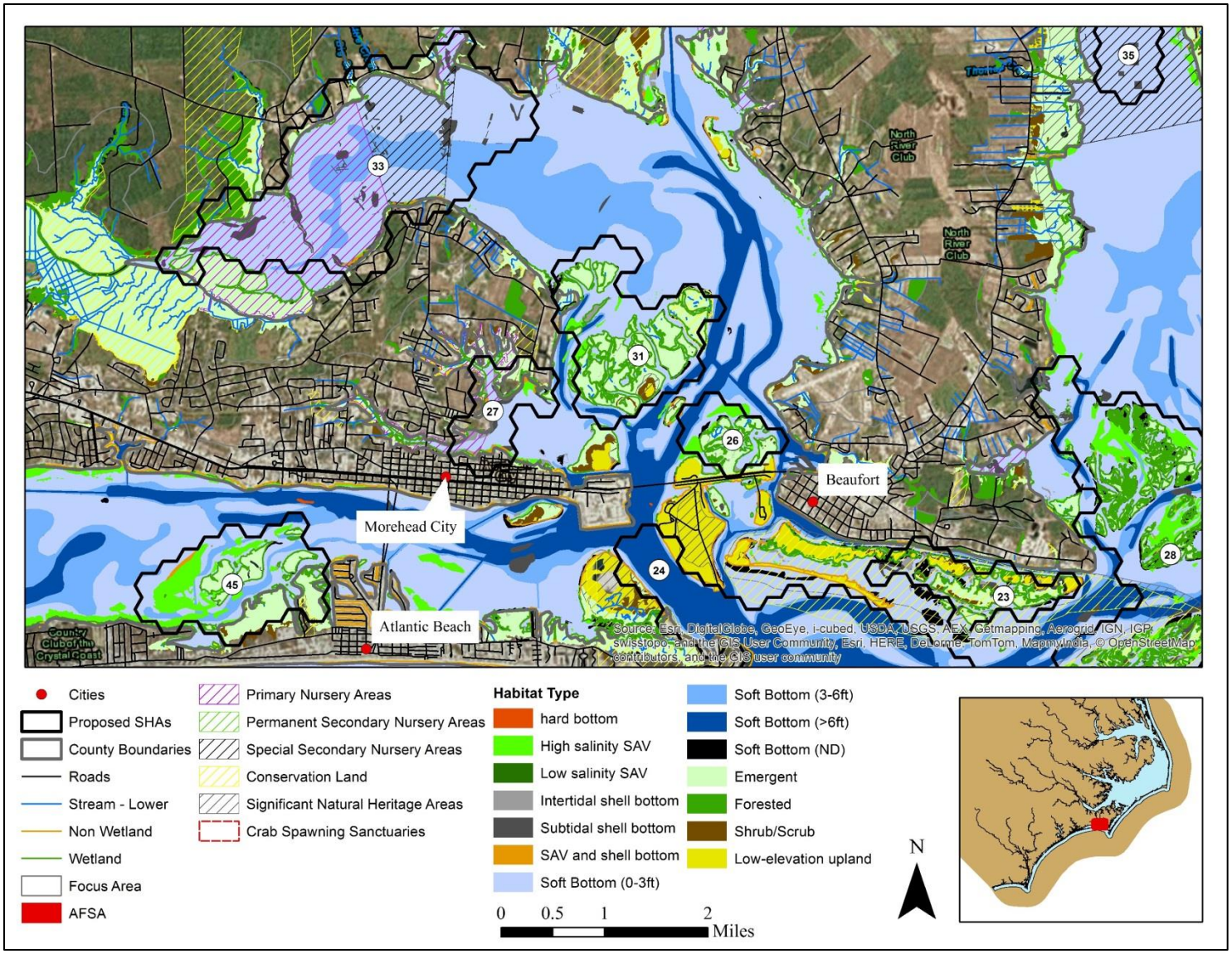
Map 19. Draft SHA nominations, Bogue and Bear inlets, Bear and Queen's creeks. Shows SHA # 18, 20, 25.



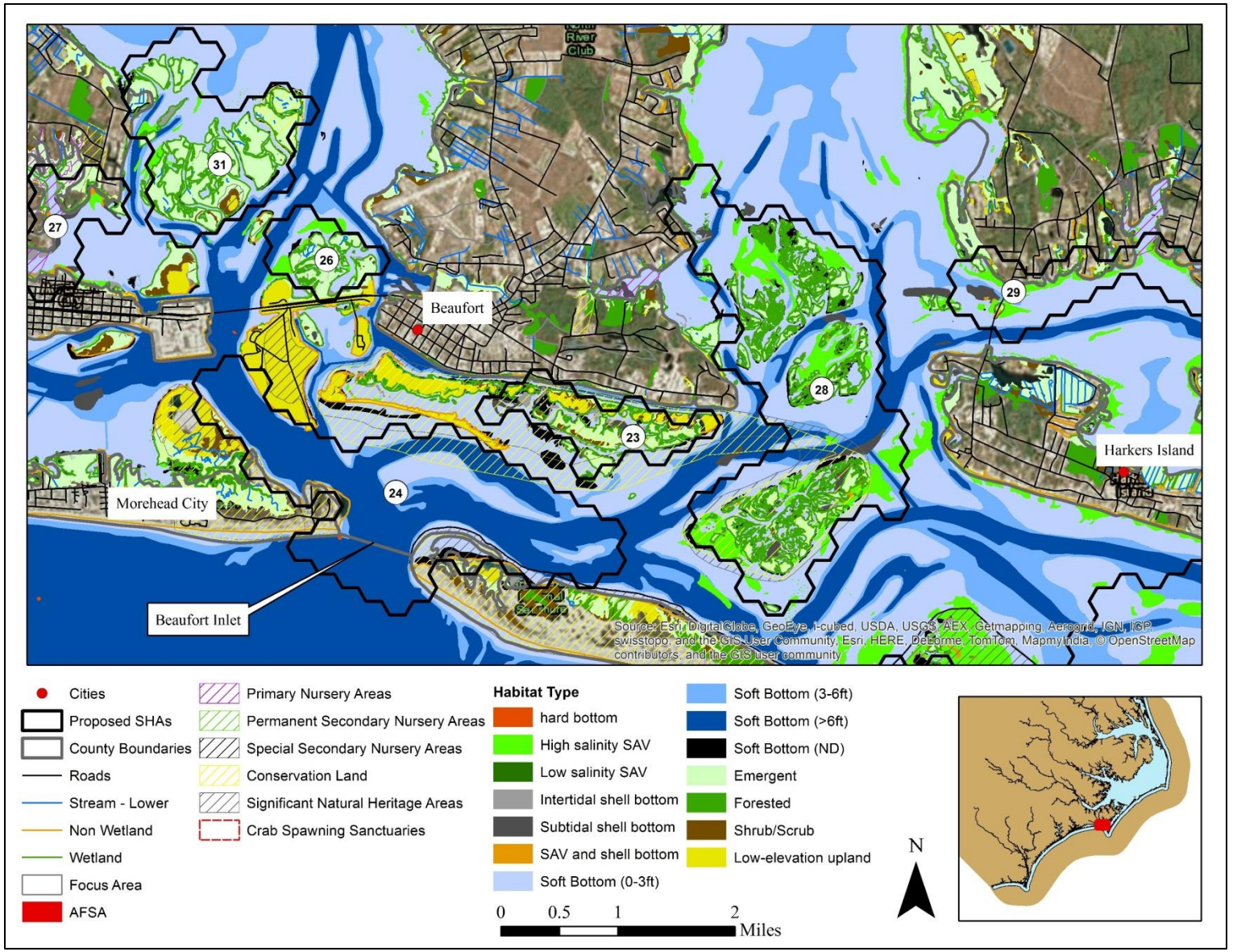
Map 19. Draft SHA nominations, western Bogue Sound and Atlantic Ocean. Shows SHA # 16, 19, 22.



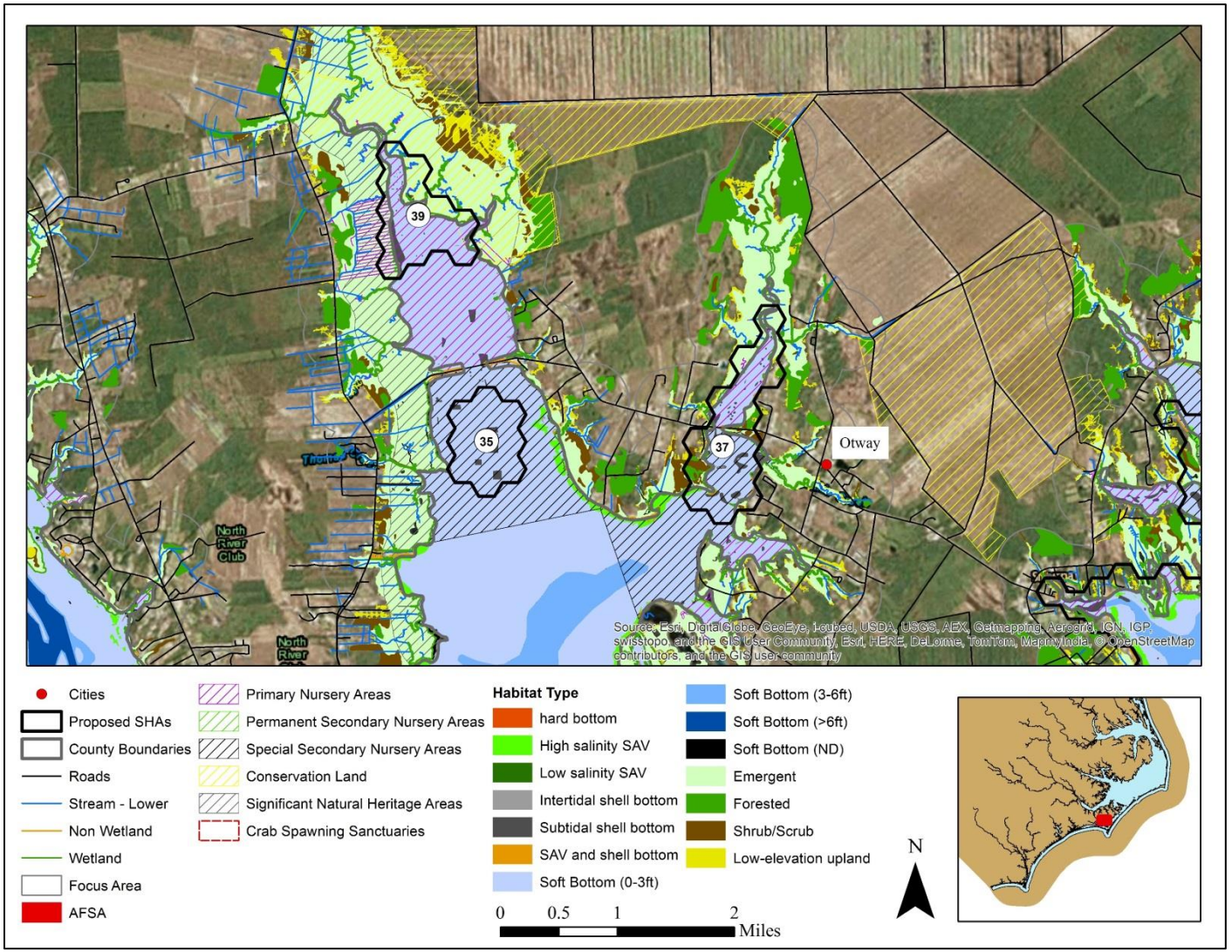
Map 20. Draft SHA nominations, Bogue Sound, Broad and Gales creeks. Shows SHA # 44, 46, and 47.



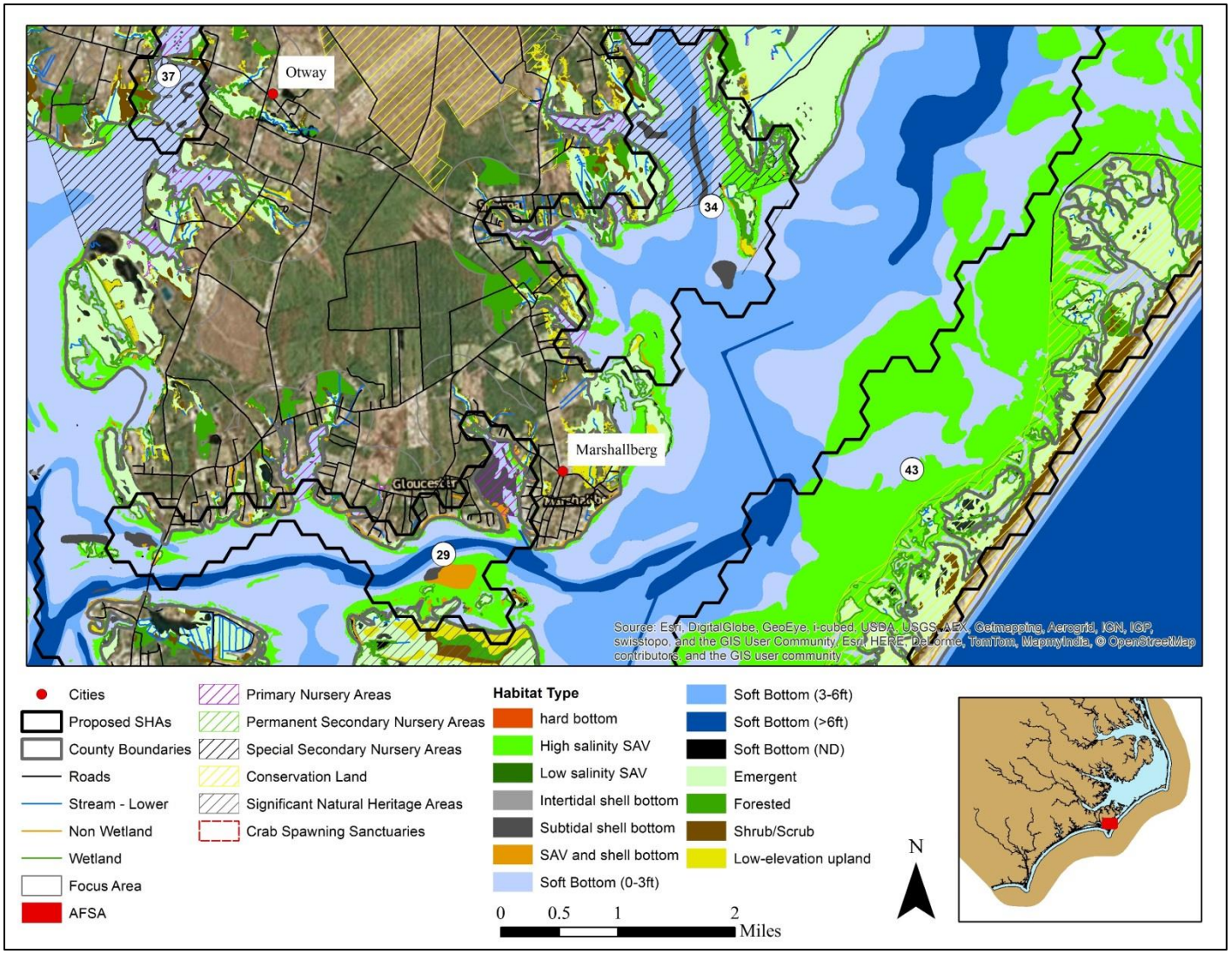
Map 21. Draft SHA nominations, eastern Bogue Sound, Hoop Pole Creek, Newport River. Shows SHA # 23, 24, 26, 27, 31, 33, and 45.



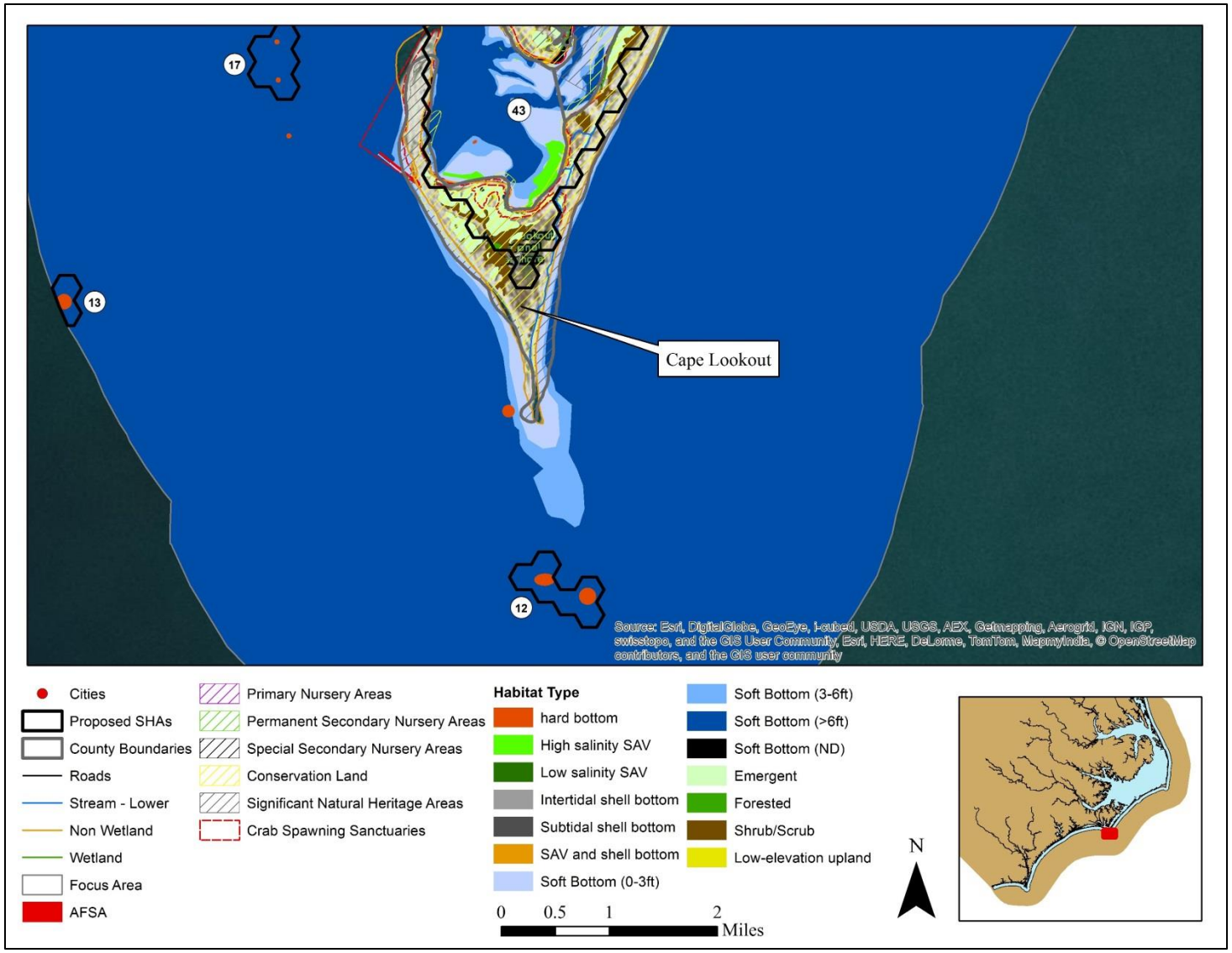
Map 22. Draft SHA nominations, Beaufort Inlet, Middle Marshes, lower North River. Shows SHA # 23, 24, 26, 28, 29, and 31.



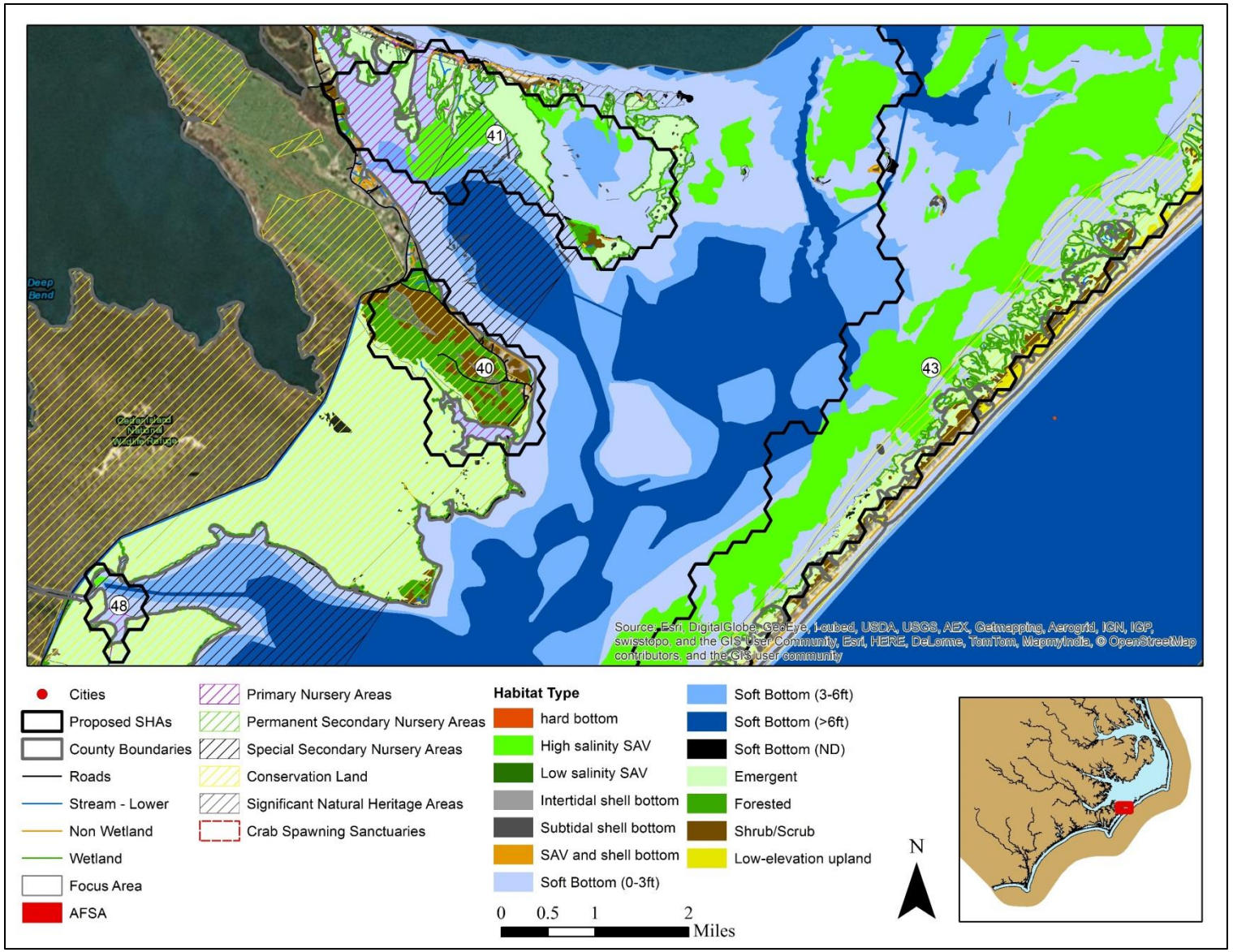
Map 23. Draft SHA nominations, North River, Ward's Creek. Shows SHA #s 35, 37, 39.



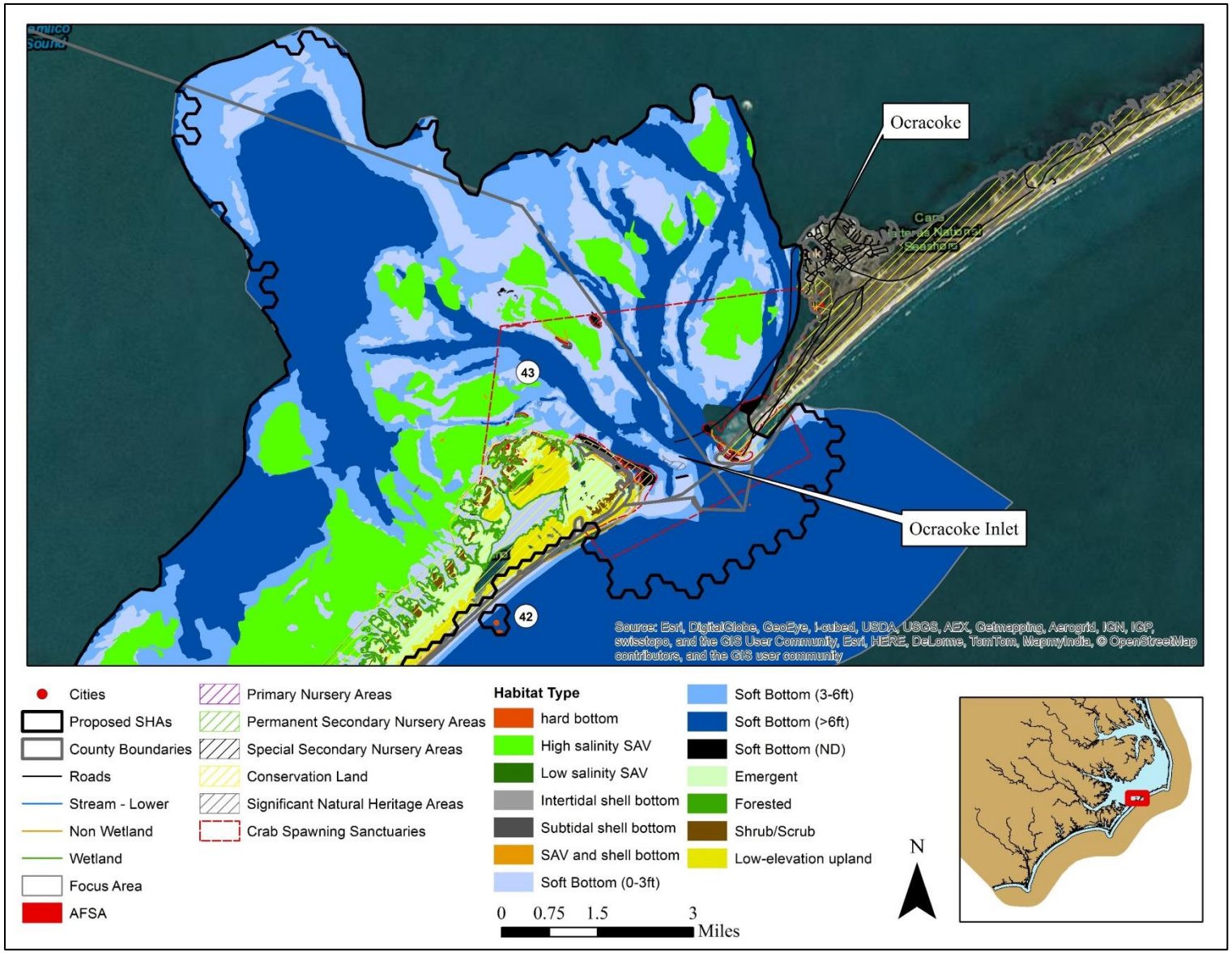
Map 24. Draft SHA nominations, the Straits, Jarrett Bay, lower Core Sound. Shows SHA # 29, 34, 43.



Map 25. Draft SHA nominations, Cape Lookout area. Shows SHA # 12, 13, 17, and part of 43.



Map 26. Draft SHA nominations, Lola, Cedar Island Bay, upper Core Sound. Shows SHA #s 40, 41, 48, and part of 43.



Map 27. Draft SHA nominations, Ocracoke Inlet. Shows SHA # 42 and upper part of 43.

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APPENDIX A: DATA/INFORMATION DIRECTORY

[To be completed for final report]

APPENDIX B: CALCULATING TOTAL ALTERATION

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

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

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

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

Severity (**S**) ratings in Table 3 were based on the individual habitat ratings for each threat listed in the threats table of the Coastal Habitat Protection Plan (CHPP) (Street et al. 2005, p. 486) and approved by the Marine Fisheries Commission, Coastal Resources Commission, Environmental Management Commission, and N.C. Department of Environment and Natural Resources in 2004. This rating ranges from 0 (no impact) to 3 (high impact) and estimates the potential impact of each alteration factor on each natural resource target or habitat type in the assessment. For water-based alteration factors (i.e., trawling or dredging), the rating in the CHPP (Street et al. 2005, p. 486) was directly applied. For land-based alteration factors (i.e., developed land use or agricultural land cover), an adjusted **S** rating is applied to all hexagons within a U.S. Geological Survey-designated hydrologic unit (HUC). 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 HUC 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 factor and habitat combination in each hexagon.

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

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

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

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

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

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

For example: a hexagon has one alteration factor – dredged channels, and contains 21 acres (70%) soft bottom and 9 acres of SAV (Figure **B-1**, Table **B-2**). Within the 9 acres of SAV, trawling is allowed over 0%

(E=0.0). The S rating of dredging on SAV is 2 (moderate) and the portion of SAV among targets in the hexagon is 30% or 0.3. The final rating for SAV would be S (2) x E (0.0) x P (0.7) = 0.0. Within the 21 acres of soft bottom, dredging is allowed over 20% (E = 0.2). The portion (P) of the soft bottom among targets in the hexagon is 70% or 0.7. The S rating for dredging on soft bottom is 1. The final rating for soft bottom is S(1) x E(0.2) x P(0.7) = 0.14. The total alteration of the hexagon would be 0.14 (0.00 + 0.14).

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

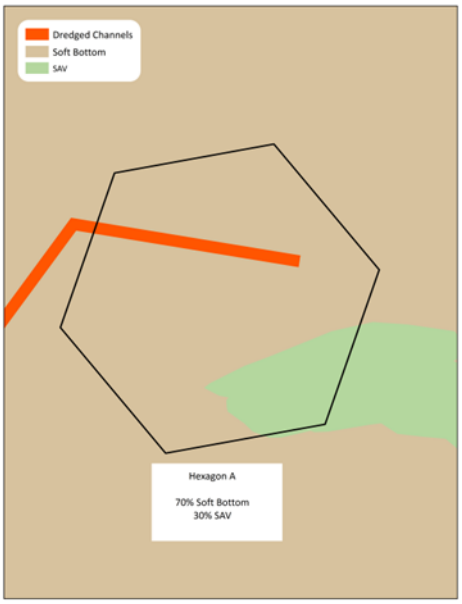


Table B-2. Calculation of hexagon alteration with only one alteration factor, but which occurs in some portion of two habitat types. S=severity, E=extent, P=portion

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

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

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

Factors	S * E

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

PROCESSING DETAILS

For the Region 3 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.

The process began by building a geodatabase of alteration data layers. Some manipulation was required to create the input layers for the alteration score. Tools were created using ArcGIS ModelBuilder with ArcGIS version 10.1. ModelBuilder allows the user to combine multiple tools and then execute them as a single process. The benefit to this approach was that it made the process transparent and easy to repeat.

The first step in creating the alteration score is to create the alterations habitat dataset. This is stored in the field ALT_HABITA in the following steps. Below is a table showing the relationship between NRT types for Region 3 and the habitat types for alteration.

Table B-4. Habitat categories used to apply unique alteration ratings.

Natural Resource Targets	Alteration Habitat Type	GIS Layer Type	Notes
Hard Bottom	Hard Bottom	Polygon	Later removed from alteration calculations and selected post-analysis by SHA AC.
High Salinity SAV	SAV	Polygon	
Low Salinity SAV			
Intertidal Shell Bottom	Shell Bottom	Polygon	
Subtidal Shell Bottom			
SAV & Shell Bottom	SAV & Shell Bottom	Polygon	
Riverine Soft Bottom (0-3ft)	Creeks and Rivers	Polygon	
Riverine Soft Bottom (3-6ft)			
Riverine Soft Bottom (ND)			
Estuarine Soft Bottom (0-3ft)	Shallow Soft Bottom	Polygon	
Palustrine Soft Bottom (0-3ft)			
Marine Soft Bottom (0-3ft)			
Estuarine Soft Bottom (3-6ft)			Later removed from alteration calculations and selected post-analysis by SHA AC.
Palustrine Soft Bottom (3-6ft)			
Marine Soft Bottom (3-6ft)			
Estuarine Soft Bottom (>6ft)			
Marine Soft Bottom (>6ft)			Later removed from alteration calculations and selected post-analysis by SHA AC.
Marine Soft Bottom (No Depth)	Deep Soft Bottom	Polygon	
Estuarine Soft Bottom (No Depth)			Later removed from alteration calculations and selected post-analysis by SHA AC.
Palustrine Soft Bottom (No Depth)	Soft Bottom (ND)	Polygon	
Emergent Wetlands			Later removed from alteration calculations and selected post-analysis by SHA AC.
Forested Wetlands			
Scrub/Shrub Wetlands			
Low Elevation Uplands	Wetlands	Polygon	
Streams (low elevation)			
Non-wetland shoreline			
Wetland Shoreline/Edge	Uplands	Polygon	
	Streams	Line	
	Non-wetland shoreline (upland)	Line	
	Wetland Edge	Line	

It is assumed that a dataset of NRT habitat types has the ALT_HABITA field populated before the alteration score calculations can begin. Begin by dissolving the Natural Resource Target line and polygon data layers

by the ALT_HABITA field to get a feature class of alteration habitats. The following describes the tools provided in the alterations toolbox. It is divided into three toolsets, which are numbered and in all caps below. Tool names are in bold, under the corresponding toolset.

1. DATA PROCESSING

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

Aggregate point features by HUC

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

Aggregate marinas by HUC

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.

Calculate marinas per shoreline

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

2. EXTENT CALCULATION

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

Land-based extent (hydrologic unit-based alteration assessment)

This tool takes the land-based alterations that need to be joined to a hydrologic unit file for the purpose of analysis and creates a master table of alterations by hydrologic unit. The alteration factors that are assessed at the hydrologic unit level are (1) minor national pollutant discharge elimination systems, (2) animal operations, (3) agricultural land use, (4) developed land use, and (5) mining operations. In Region 2, marinas were assessed at the hydrologic unit level along with wasteponds. There were no wasteponds to assess in Region 3 and marinas were assessed at a finer scale, using the shellfish sanitation closure areas as the unit for assessment. The tool also creates a table giving the amount of each hydrologic unit in each hexagon; which is used to calculate the land-based alteration scores for hexagons that cross hydrologic unit boundaries.

INPUTS:

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

OUTPUTS: (*the following tables are output as dbfs*)

1. hu_alt_factors_table.dbf: gives the amount of each alteration factor present by hydrologic unit

Field Name	**Description**
HUC 12_new	Twelve-digit hydrologic unit code.
hu_area	Area of hydrologic unit measures in square meters.
min_npdes	Number of minor NPDES sites per hydrologic unit.
anops	Number of animal operations per hydrologic unit.
ag_use	Relativized proportion of agricultural land use per hydrologic unit.
dev_use	Relativized proportion of developed land per hydrologic unit.
mines	Number of mining operations per hydrologic unit.

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

Field Name	Description
Unique_ID	Hexagon assessment unit unique identifier.
HUC_12_new	Twelve-digit hydrologic unit code.
hu_area	Total area of hydrologic unit measured in square meters.
hex_area	Area of hydrologic unit within each hexagon unit measured in square meters.
MAX_HEX_AR	The maximum area of a given hydrologic unit within a single hexagon assessment unit measured in square meters.

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

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

Water-based extent

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

INPUTS:

1. Polygon feature classes of the areas affected by water-based alteration factors:
    a. Drained wetland areas
    b. Dredged areas
    c. Impounded areas
    d. Canals and boat basins
    e. Bridge constrictions
    f. Docks and bridges
    g. Trawling-temporarily open
    h. Trawling-permanently open
    i. Marinas assessed by shellfish growing areas (SGAs)
    j. Clam harvesting areas
    k. Major NPDES

2. Line feature classes of areas affected by water-based alteration factors:
    a. Seawalls feature classes
    b. Riprap feature class
    c. Ditch lines feature class
    d. Culvert obstructed areas feature class

3. Alteration habitats linear and polygon feature classes

4. Hexagon assessment unit feature class

OUTPUTS:

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

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

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

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

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

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

4. **seawalls_by_hex_table.csv** - Gives the amount of seawalls in each hexagon.

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

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

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

6. **streams_by_culvert_by_hex.csv** - Gives the total length of streams within hexagons affected by culverts.

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

7. **culvert_by_hex.csv-** Gives the length of culvert-affected areas within each affected hexagon.

Field Name	
Unique_ID	
ALT_HABITA	
culv_leng	

4. shoreline_by_hex_table.csv- lists the shorelines found in each hexagon

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

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

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

R Tools for use in calculating alterations

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

    a. **ALT_HABITA** – alteration habitat type, must be one of the following: "*creeks and rivers*", "*deep soft bottom*", "*shallow soft bottom*", "*SAV and shell bottom*", "*SAV*" , "*shell bottom*", "*soft bottom (ND)",* "*upland*", "*wetland*".
    b. **Unique_ID** – unique hexagon assessment unit identifier.
    c. **alt_area** – area of habitat intersection by the alteration factor in each hexagon.
    d. Fields for any polygon based alterations considered. Currently, they include the following: "*canal_bb*", "*brdge_cons*", "i*mpounded*", "*docks_br*", "*dredged*", "*drained*", "*marinas*", "*major_npdes*", "*trawl_perm ",* "*trawl_temp*".

        i. Each row gives the presence/absence (1/0) of one specific factor for each hexagon.
        ii. Each hexagon has multiple rows, one for each habitat type x factor combination.

2. Table listing the overlapping line-based alterations and linear habitat combinations per hexagon with the following fields **(alt_lines_by_hex_final.csv)**:

   a. **ALT_HABITA** – alteration habitat type, must be one of the following: "*Non Wetland Edge", "stream", and "Wetland Edge".*
   b. **Unique_ID** – unique hexagon assessment unit identifier.
   c. **alt_length** – area of habitat intersection by the alteration factor in each hexagon.
   d. Fields for any linear-based alterations considered. Currently, they include the following: "*canal_bb*", "*brdge_cons*", "i*mpounded*", "*docks_br*", "*dredged*", "*drained*", "*marinas*", "*major_npdes*", "*trawl_perm ","* trawl_temp".

      i. Each row gives the presence/absence (1/0) of one specific factor for each hexagon.
      ii. Each hexagon has multiple rows, one for each habitat type x factor combination.

3. Table giving amount of each polygon habitat in each hexagon with the following fields (**hab_by_hex_table_no_marine.csv**):

   a. **ALT_HABITA** – alteration habitat type.
   b. **Unique_ID** - unique hexagon identifier.
   c. **hab_area** – total area of particular habitat type within a hexagon.

4. Table giving amount of each linear habitat in each hexagon with the following fields (**lines_by_hex_table_NEW.csv**):

   a. **ALT_HABITA** – alteration habitat type.
   b. **Unique_ID** - unique hexagon identifier.
   c. **length_new** – total area of particular habitat type within a hexagon.

5. Alteration severity table (**alteration_factor_weighting_water.csv**):

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

6. Seawalls by hexagon (**seawalls_by_hex_table.csv**):

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

8. Length of streams with an amount ditched attribute (**ditched_by_hex_final.csv**). Necessary attributes:

    a. **Unique_ID** – hexagon assessment unit unique identifier.
    b. **ALT_HABITA** – linear habitat type for alteration (streams only).
    c. **ditch_le** – total length of ditched feature within each hexagon, measured in meters.
    d. **prop_ditched** – proportion of total stream length that is ditched.
    e. **length_new** – total amount of linear habitat type within each hexagon, measured in meters.

9. Length of streams with an attribute signifying the amount affected by culverts (**streams_by_culvert_by_hex.csv**). Necessary attributes:

    a. Unique_ID – hexagon assessment unit unique identifier.
    b. ALT_HABITA – habitat type for alteration (streams only).
    c. **culv_len** – length of culvert-affected features, measured in meters.

10. Length of shoreline affected by riprap (**riprap_by_hex.csv**). Necessary attributes:

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

11. Length of shorelines within each hexagon (**shoreline_by_hex_table.csv**)
    Note: ultimately I don't think this is needed/was used because it's essentially the same thing as lines_by_hex_table_NEW.csv.

    a. **Unique_ID** – hexagon assessment unit unique identifier.
    b. **ALT_HABITA**– habitat type for alteration (non-wetland shoreline, wetland shoreline).
    c. **length_new** – length of habitat types within each hexagon.

Output files:

1. Severity multiplied by extent for all water based factors for each hexagon, in dbf and csv form:
    a. wbse_05272014.csv
    b. wbse_05272014.dbf

Land based severity extent calculations.r

Input files:

1. Table of factors for each hydrologic unit (**hu_alt_factors_table.dbf**):
    a. **HUC_12_new** – US Geological survey hydrologic unit code.
    b. **hu_area** – area of hydrologic unit in meters squared.
    c. *Scaled* values for the affected amount for each hydrologic unit:
        i. **min_npdes** – number of sites per hydrologic unit (includes aquaculture facilities) divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
        ii. **anops** – number of animal operations sites per hydrologic unit divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.
        iii. **dev_use** – proportion of area of each hydrologic unit in the developed land use class.
        iv. **ag_use** – proportion of area of each hydrologic unit in the agricultural land use class.
        v. **mines** – number of mining operation sites per hydrologic unit divided by the maximum number of sites in a hydrologic unit to create a scaled ratio.

2. Table giving amount of each polygon habitat in each hexagon (**hab_by_hex_table_no_marine.csv**). The necessary attributes include:
    a. **ALT_HABITA** – polygon habitat type for alteration.
    b. **Unique_ID** – hexagon assessment unit unique identifier.
    c. **hab_area** – area of habitat in meters squared.

3. Table identifying which hydrologic unit a hexagon is in (if a hexagon has more than one hydrologic unit it will have more than one line)(**huc_by_hex_table_new_final.csv**):
    a. **Unique_ID** – hexagon assessment unit unique identifier.
    b. **HUC_12_new** – US Geological Survey hydrologic unit code.
    c. **hu_area** – area of each hydrologic unit.
    d. **hex_area** – area of each hexagon assessment unit unique identifier.
    e. **FREQUENCY**- number of HU's a hexagon intersects.
    f. **MAX_HEX_AR –** maximum area of hexagon in one hydrologic unit.

4. Alteration severity table (**alteration_factor_weighting_land.csv**)
    d. **ALT_HABITA** – habitat types (rows).
    e. Alteration list – must match names exactly as they appear in the R alteration file (columns).

5. Intersection of closed shellfish areas with habitats in the study area (**shellfish_by_hex_no_marine.csv**). Necessary attributes.
    a. **ALT_HABITA** – alteration habitat type.
    b. **Unique_ID** – hexagon assessment unit unique identifier.
    c. **shell_area** – area of overlap between closed shellfish areas and alteration habitat types.

Output file:

1. **lbse_05272014.csv**
2. **lbse_05272014.dbf**

Alteration scores.r

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

Inputs:

1. Severity by extent for water-based alterations (**wbse_05272014.csv**)
2. Severity by extent for land-based alterations (**lbse_05272014.csv**).
   Note: this is already aggregated so that there's one row per hexagon whereas the other severity by extent file is not.

3. Table giving amount of each polygon habitat in each hexagon (**hab_by_hex_table_no_marine.csv**)
   a. **ALT_HABITA** – alteration habitat type
   b. **Unique_ID** – hexagon assessment unit unique identifier
   c. **hab_area** – area of habitat features, measured in meters squared

4. Length of lines in each hexagon (**lines_by_hex_table_NEW.csv**)
   a. **ALT_HABITA** – linear habitat type for alteration
   b. **Unique_ID** – hexagon assessment unit unique identifier
   c. **length_new** – length of feature, in meters

Outputs:

1. **alt_scores_05272014.csv** - combined alteration scores for all hexagons. Attributes:
   a. **ID** – hexagon assessment unit unique identifier.
   b. **r3_alt_score** – alteration score
2. **hab_scores05272014.csv –** alteration scores broken down by habitat type per hexagon. One line per hexagon gives the severity * extent * portion for each habitat type in each hexagon.
3. **ind_scores_05272014.csv** - alteration scores broken down by alteration factor by hexagon. One line per hexagon gives the severity * extent * portion for each alteration factor for each hexagon.

APPENDIX C: PREPARING THE MARXAN FILES

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

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

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

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 3, 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

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 2 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 unit 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

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 3 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

Planning units vs. Species file (puvspr.dat)

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

the polygon (r3_nrt_polygons) and line (r3_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

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 D: 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.

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 C-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. Based on these results, the number of runs was set to 500 for the rest of the analysis.

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. The influence of the three different parameters on the Marxan solutions was examined to ensure that the Marxan

analysis was equally considering all three parameters. 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 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 C-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 C-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 C-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 C- 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 committee decided to use the solution with a BLM of 0.01 as the basis for the corroboration phase of the analysis, but to only consider clusters that were greater than 3 hexagons as potential SHAs.

Table D-1. Sensitivity runs to calculate an efficiency analysis of the boundary length modifier.

Run	BLM	Boundary Length	Area (acres)	Cost
1	0	0	88,883	835
2	0.00001	485,600	94,566	839
3	0.00005	444,223	93,577	839
4	0.0001	411,920	95,092	829
5	0.0005	337,589	99,304	843
6	0.001	300,495	98,592	847
7	0.005	227,373	100,765	1,031
8	0.01	210,307	100,284	1,262
9	0.05	202,579	123,221	3,619
10	0.1	221,583	148,139	5,660
11	0.5	227,012	195,628	9,291

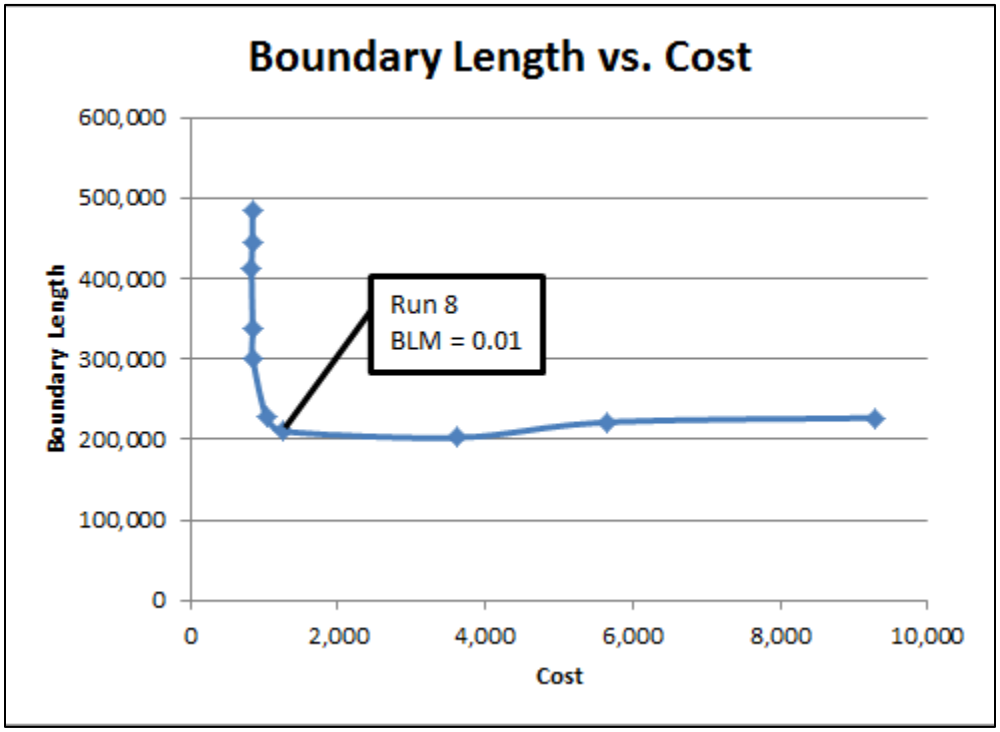


Figure D- 1. BLM Efficiency analysis results comparing boundary length to cost.

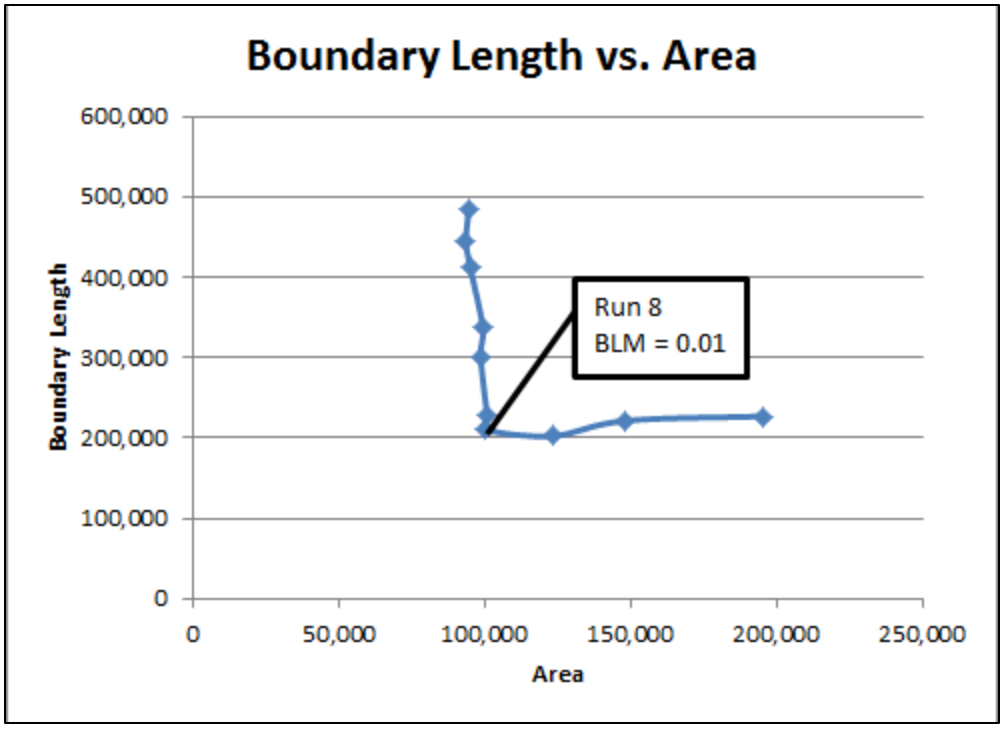
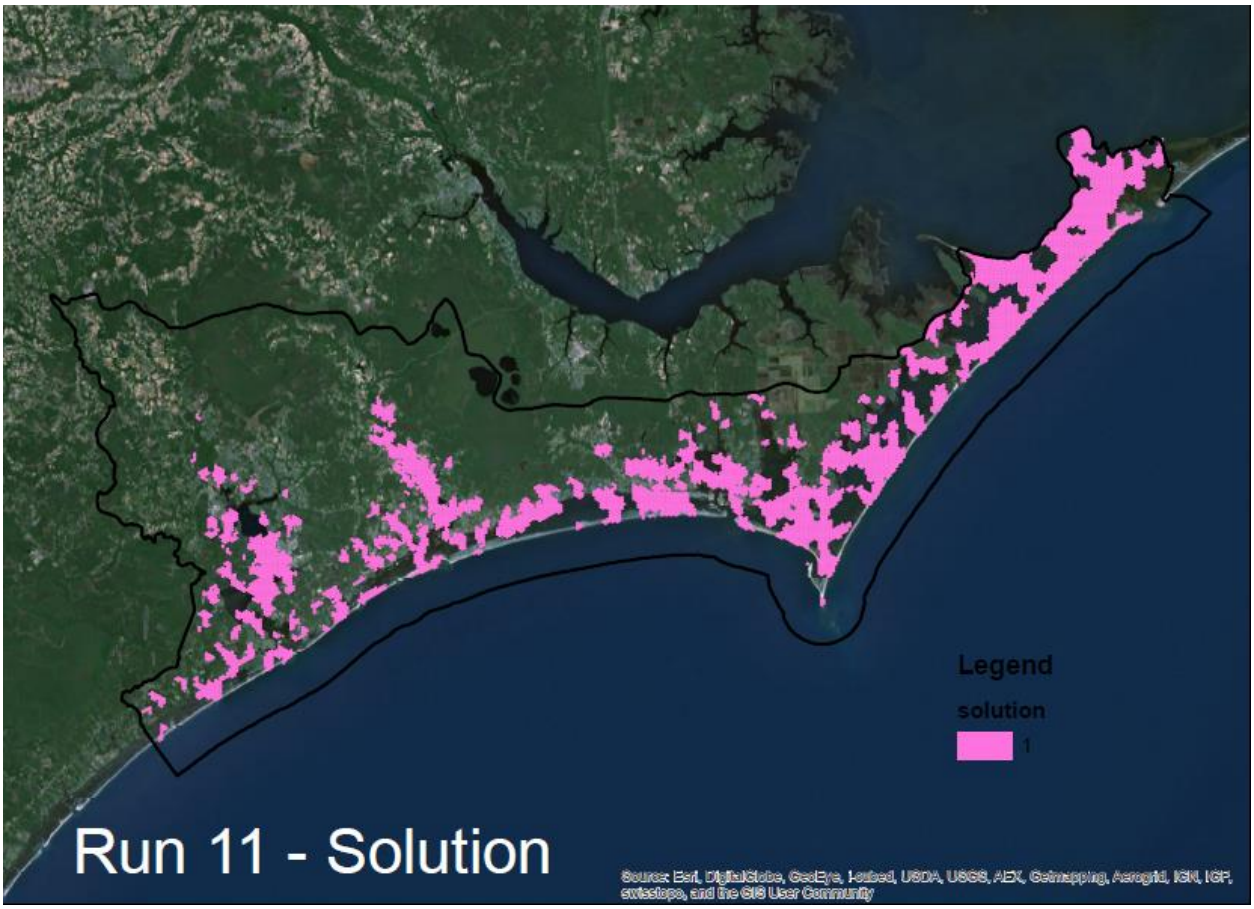


Figure D-2. BLM Efficiency analysis results comparing boundary length to area.

Map 28. SHA Region 3 sensitivity run 2 with a BLM=0.0001 and 500 runs.



Map 29. SHA Region 3 sensitivity run 11 with BLM=0.5 and 500 runs.

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 E: PUBLIC MEETING COMMENTS

In October 2014, input was sought regarding the SHA nominations at five MFC Advisory Committee meetings from committee members and the public. Suggested changes were presented to the SHA Region 3 Advisory Committee via email for comment and approval (Table E-1).

King's Creek and the unselected area of Stump Sound were recommended to be added due to their biodiversity of habitats, and productive oysters, speckled trout, red drum, and other priority species. French Creek and Brown's Inlet were recommended for removal. Both of these are heavily utilized by Camp Lejeune for military operations and have disturbed bottom conditions. Comments also suggested removing an area near the Surf City bridge due to multiple alterations, and small hard bottom areas (less than one single hexagon).

The Advisory Committee did not disagree with any suggestions and provided further corroborating information regarding why some areas were selected. DMF's Management Review Team also reviewed comments from the advisory committees and supported the changes with the exception of adding the rock outcrop in the White Oak River as a SHA since the area, thought to be spawning grounds for American shad, was not used by priority species. They also noted that reviewing SHAs in five year intervals may not be possible with current staff loads.

Table E-1. Summary of comments from MFC Advisory Committee Meetings.

Advisory Committee	Passed Motion	Comments
Southern	Recommend that MFC support the proposed SHA nominations as presented.	Consider excluding the SHA adjacent to Surf City bridge- development, marina, dredged channel, closed shellfish.
Northern	Recommend that MFC support the proposed SHA nominations as presented.	
Northern	Recommend that MFC 1) encourage that the SHA information be disseminated to local government and other stakeholders, and 2) to review every five years (determine what is working and what isn't and change accordingly) to improve their effectiveness.	Needs teeth; need to make local governments aware so they can try to protect.
Habitat and Water Quality	Recommend that MFC approve proposed SHA nominations, with condition that they may submit potential changes until Nov 1.	Suggested adding the rock outcrop in the upper White Oak River in Maysville (shad, river herring run) and look at Gene Balance data re old reefs in northern portion of Region 3- add if any.
Finfish	Recommend that MFC support draft SHAs contingent on suggested changes (remove Brown's Inlet and add King's Creek and remainder of Stump Sound).	Remove Browns Inlet- military prohibited and lot of ordinance on bottom; Add King's Creek mouth to horseshoe curve– oysters, blue crab, shrimp, spotted sea trout, red drum abundant; very productive, not

		developed. Consider joining Bear and Bogue Inlet SHA units; consider adding Freeman Creek; check on why French Creek and Northeast Creek was added; how do SHAs compare to test case selections
Shellfish/ Crustacean	Recommend that MFC support draft SHAs with addition of King's Creek and remainder of Stump Sound, and removal of ocean hard bottom that is only one hexagon.	Consider excluding hard bottom that is a single hexagon; Add King's Creek – not only productive fisheries, diversity of habitat, SAV, not developed; consider extending Turkey Creek upstream; questioned why so little of Queens Creek selected; questioned why Jarrett Bay selected and not other similar bays (Nelson, Thoroughfare)