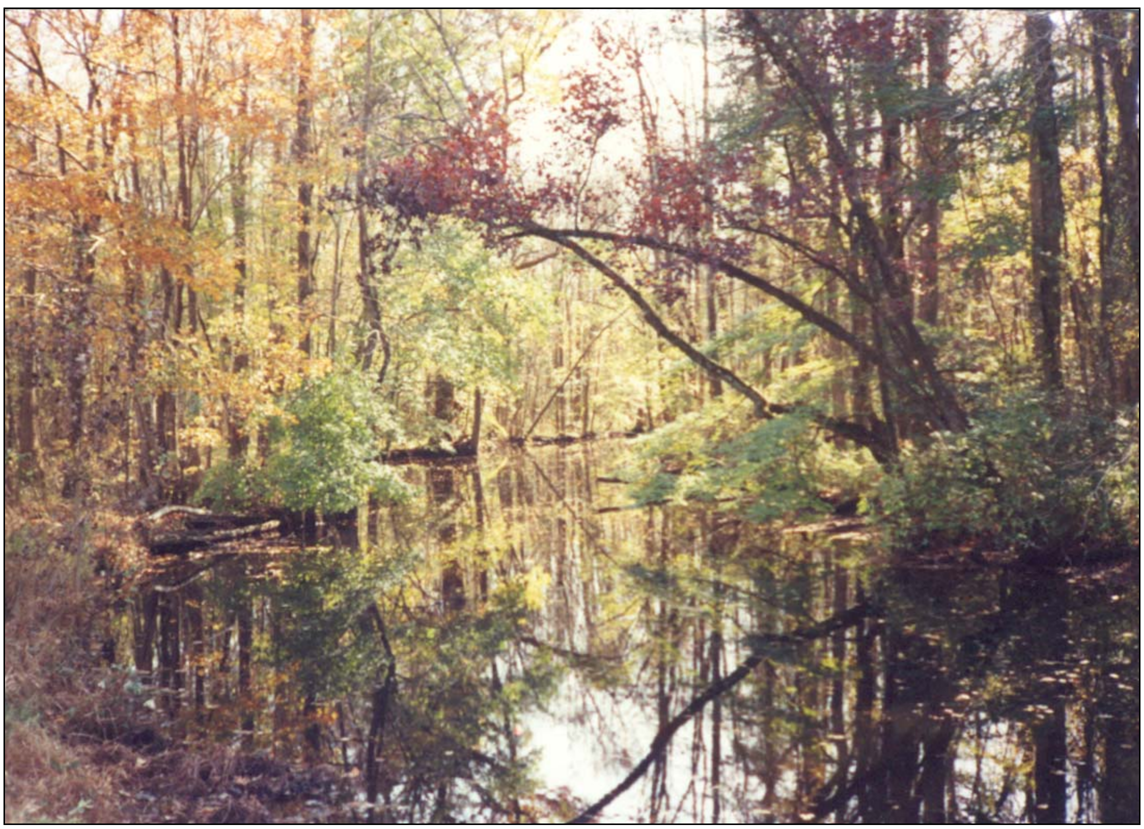
STRATEGIC HABITAT AREA NOMINATIONS FOR REGION #1:
Albemarle Sound to Northeastern Coastal Ocean of North Carolina

FINAL

Written by staff of Division of Marine Fisheries Habitat Section
Reviewed and endorsed by Strategic Habitat Area Regional Advisory Committee
Final presented to the Marine Fisheries Commission January 2009



ACKNOWLEDGEMENTS

Several DMF staff played an important role in developing the process documented in this report. Scott Chappell performed the analysis and writing, with assistance from Anne Deaton, Katy West, and Brian Boutin. Anne, Katy, and Brian were also involved in fine-tuning the application of methods and presentation of information to the advisory committee. Ballingham Chepuri, from the DENR IT section, assisted with the creation of various map products for the analysis. Sara Winslow and Kathy Rawls, from the Elizabeth City DMF office, contributed their extensive experience with fisheries species and habitat conditions in the region. We would also like to thank Jeanne Hardy for recording our meetings and providing refreshments. Next, we appreciate the work of Tim Ellis, Sea Grant research fellow, corroborating estimated habitat quality with actual fish data. Finally, we thank the regional advisory committee members for laboring through the highly technical meetings needed to fully address the issue of Strategic Habitat Areas in northeastern North Carolina.

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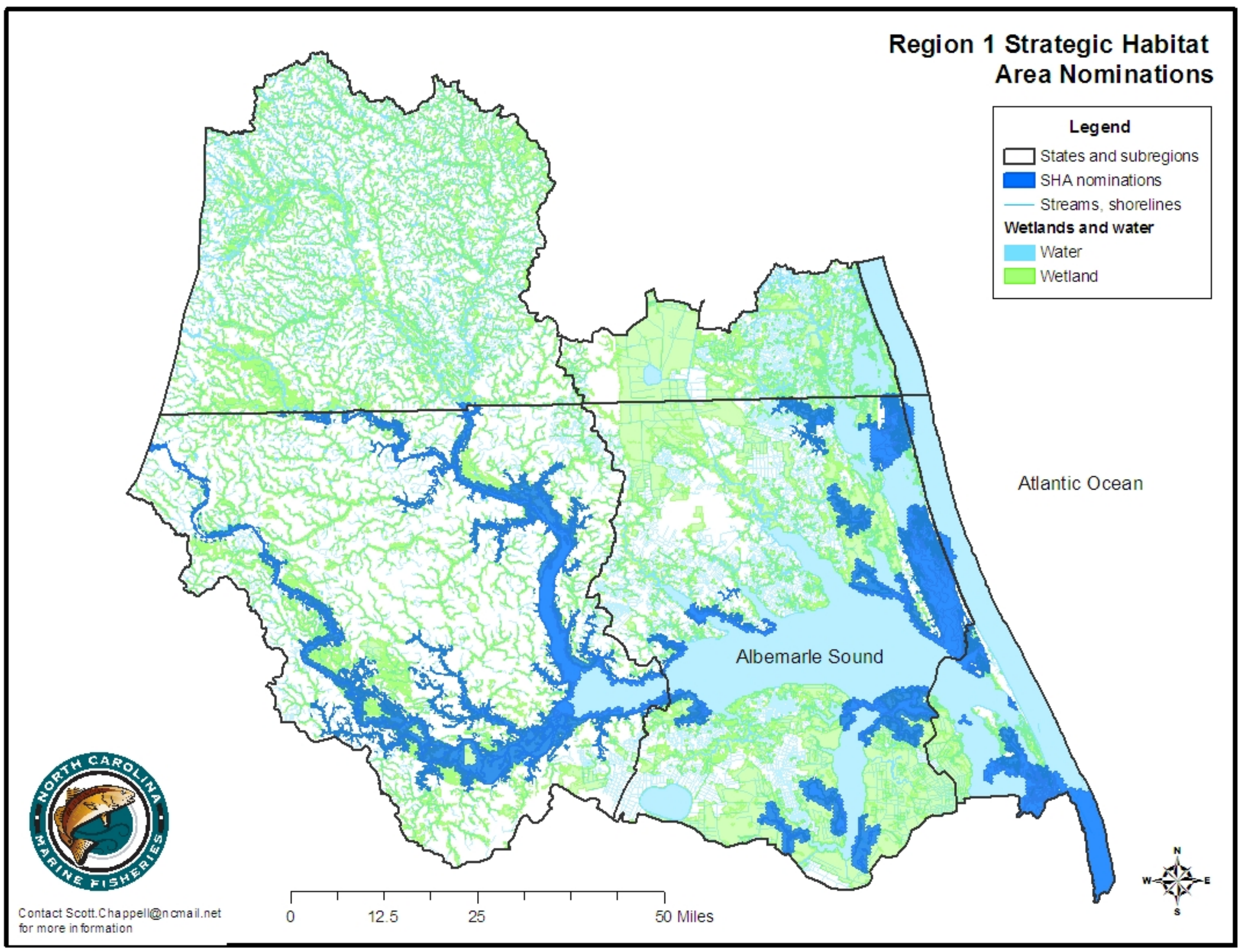
LIST OF ABBREVIATIONS

NAME	Abbreviation
CGIA	North Carolina Center for Geographic Information
COE	United States Army Corps of Engineers
DCM	North Carolina Division of Coastal Management
DEH-SS	North Carolina Division of Environmental Health – Shellfish Sanitation
DMF	North Carolina Division of Marine Fisheries
DOT	North Carolina Department of Transportation
DWQ	North Carolina Division of Water Quality
DWR	North Carolina Division of Water Resources
FWJ	North Carolina Fishing Water Jurisdictions
HU	Hydrologic unit
MARXAN	Site selection program
MFC	North Carolina Marine Fisheries Commission
NHD	National Hydrologic Dataset
NOAA	National Oceanographic and Atmospheric Administration
NRT	Natural resource targets
NWI	National Wetlands Inventory
SAV	Submerged aquatic vegetation
VDEQ	Virginia Department of Environmental Quality
WRC	North Carolina Wildlife Resources Commission
WTP	Water treatment plant
WWTP	Waste water treatment plant

EXECUTIVE SUMMARY

Strategic Habitat Areas represent priority habitat areas for protection due to their exceptional condition or imminent threat to their ecological functions supporting estuarine and coastal fish and shellfish species. Identification and designation of SHAs is a CHPP implementation action. The identification of SHAs was conducted in a two step process: 1) using GIS-based habitat and alteration data in a computerized site-selection analysis, and 2) verifying and modifying information based on input from a scientific advisory committee. Staff and advisory committee specified representation levels for 42 habitat types, or natural resource targets. There were also 18 alteration factors that were represented geospatially (i.e., hydrologic alterations, water quality degradation). The site selection program MARXAN was used to select areas that met representation levels while also minimizing alteration. The scientific advisory committee then modified the computer results based on their unique knowledge and experience. The resulting SHA nominations for 20 areas encompass approximately 20% of the entire area of natural resource targets in Region 1. The SHAs were corroborated with biological data, ecological designations, and specific knowledge of the area. The SHA nominations will be incorporated into conservation and restoration planning efforts.



INTRODUCTION

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

SHA designations will be based on regional analyses that identify optimally placed habitat areas of various ecological condition (exceptional or at risk). SHAs may include areas that have already been protected by other designations, as well as areas not currently recognized in any way. A network of designated SHAs providing habitat connections throughout North Carolina's coastal waters should ensure that the complex life history needs of all species are met. Once SHAs are designated in rule, resource managers may address gaps in existing management and take steps to prevent further alteration of the system as a whole. Thus, the necessary protections may go above and beyond current measures designed to protect habitat. Even before designation in rule, conservation agencies may incorporate candidate SHAs in their site selection process for acquisition, enhancement or restoration projects.

The identification of SHAs addresses the continuing degradation and loss of important habitats referenced in the CHPP (Street et al. 2005). The current rules and policies of the resource management agencies fail to adequately address the individually small but cumulatively large conversions and alterations of fish habitat for development and associated human activities (Street et al. 2005). Eventually, resource management and conservation agencies must address the issue of cumulative impacts in terms of, "where to draw the lines." On a regional scale, the question of, "where to draw the lines," is addressed by the setting of representation levels for interdependent components (natural resource targets) of the estuarine and coastal ecosystem. Strategic Habitat Areas are founded upon these representation levels.

This report documents the selection of SHA candidates in Region 1, encompassing Albemarle Sound in northeastern North Carolina, and follows the nomination report format specified in the SHA report.

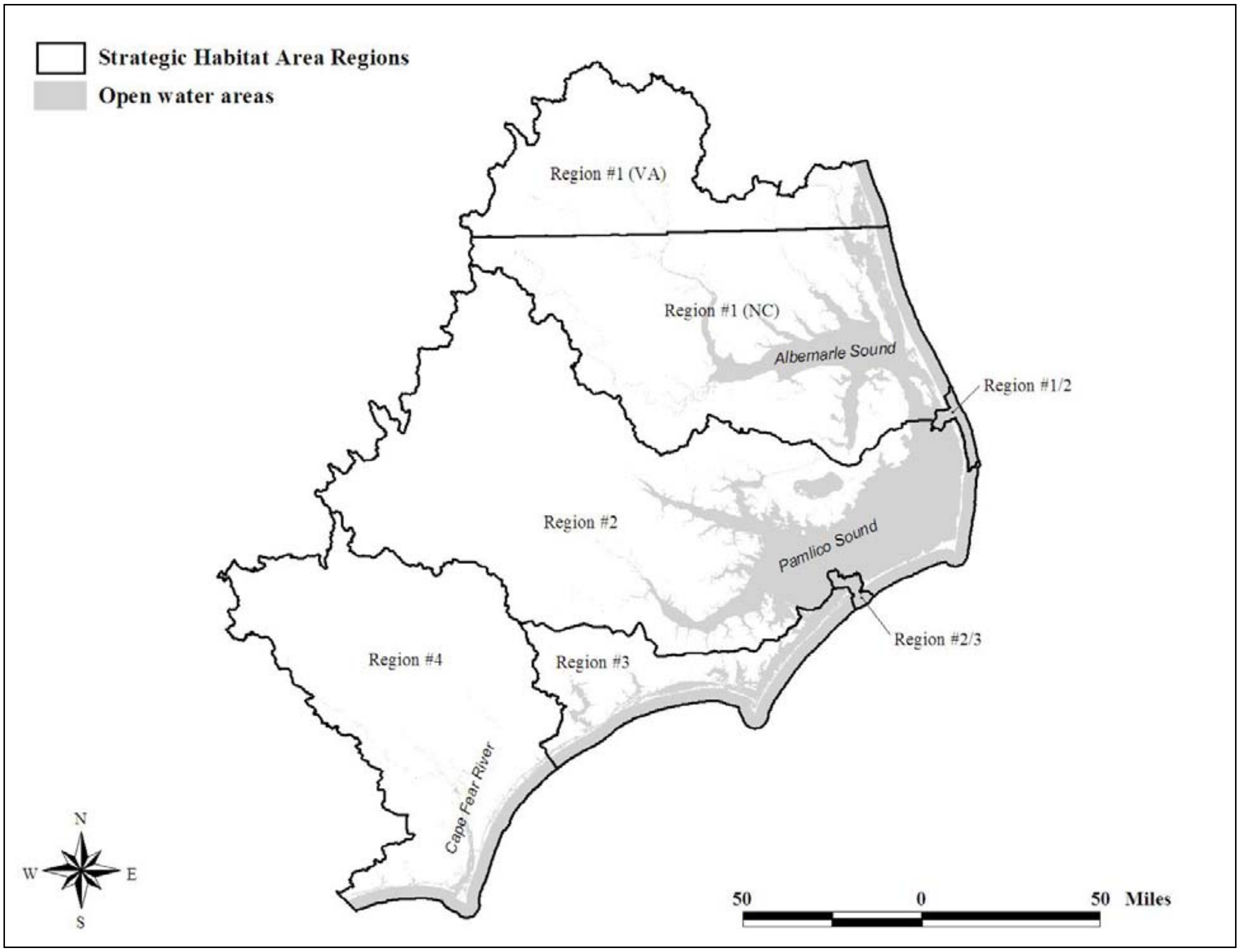
GEOGRAPHIC SCOPE OF REGION 1

Region 1 is the focus of SHA nominations in this report. This region includes the waters and adjacent wetlands draining into and out of Albemarle Sound through Oregon Inlet to the adjoining coastal ocean (Map 1). It includes the sounds and tributaries of the Albemarle, Currituck, Roanoake and Croatan sounds, and the nearshore ocean. The majority of the Albemarle Sound system is lined with bottomland hardwood wetland forests. The eastern sounds are lined with brackish marsh and support SAV habitat and scattered areas of shell bottom habitat. Because Oregon Inlet is the only inlet in the northern portion of the Albemarle-Pamlico system, it is a critical fish corridor. This region has long been known for his abundance of fishery resources. Striped bass, river herring, and blue crab have been traditional fisheries of the Albemarle region.

The boundaries of the study area were based on a combination of USGS 12-digit hydrologic units and the CHPP management units for Albemarle Sound, Chowan River, and Roanoke River (Street et al. 2005). This area includes the majority of Division of Water Quality's (DWQ) Pasquotank, Roanoke, and Chowan river basins. The region intersects several counties, cities, and municipalities in both North

Carolina and Virginia (Map 1). Within Region 1, all six habitat types identified in the CHPP are present including: water column, soft bottom, shell bottom, submerged aquatic vegetation, wetlands and oceanic hard bottom (Street et al. 2005). The Albemarle Sound area was the focus of this report primarily due to concern over depleted river herring stocks, which the MFC put a fishing moratorium on in 2007. In addition, this relatively less developed region is currently under growing development pressure, being marketed as the "Inner Banks", and has been described as the last frontier of rural coastal North Carolina.

Map 1. Regional boundaries for Strategic Habitat Areas delineations.



METHODOLOGY

The regional expert panel for Region 1 used the master lists from the SHA report to select relevant natural resource targets (NRTs) and alteration factors (AFs). The SHA report defines “natural resource targets” as the habitats or ecological functions that represent essential or unique components of the system, of which some portion has been identified as a priority for protection, enhancement or restoration. “Alteration factors” are human activities, features or water quality indicators that can affect the condition of the natural resource targets. The preparation of data for each target and alteration factor is described in detail later in this report.

A Duke University master’s project investigated possible methodology for SHA identification in North Carolina and recommended use of a GIS-based site-selection computer program (MARXAN) (Smith 2005). Consequently, the SHA report recommended use of MARXAN as a decision support tool to identify SHAs. **MARXAN utilizes available geospatial information on the distribution of habitats and alteration factors to find a subset of habitat areas that meet specified goals for representation while minimizing the degree of alteration represented.** A major assumption of this conceptual framework is that alteration = degradation. The accuracy of the computer output is limited by the quality and representation of the spatial data included in the assessment.

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

DESCRIPTION OF SELECTION TOOL

The site-selection program MARXAN was used initially to identify habitat areas for possible SHA designation. This program uses an optimization algorithm (series of mathematical computations) called “simulated annealing” to rapidly consider various solutions until an optimal arrangement and distribution of habitats is arrived at that includes the largest amount of desired habitat areas, while minimizing the selection of disturbed or altered areas (Ball and Possingham 2000; Possingham et al. 2000). Note that the standard terminology usually associated with MARXAN programming has been modified in this report to terms more appropriate for applications of this tool in coastal North Carolina. For example, standard MARXAN terminology for NRT and AF is simply target and cost factor, respectively.

The MARXAN program uses three basic layers of information – a geospatial layer of the natural resource targets (habitat map), an alteration layer that depicts the location of alteration factors, and a hexagonal modeling grid that divides the project area into a honeycomb of standardized units for analysis (see Appendix A for data/information directory and Appendix B for creating the MARXAN input files). The site-selection program then analyzes the type and quantity of natural resource targets occurring in each hexagon and their relative condition (determined by the alteration layer). The alteration layer expresses the overall impact of all alteration factors in each hexagon. The site-selection tool makes it possible to methodically and systematically select priority conservation areas considering multiple species, their associated habitats, and various socio-economic factors represented as alterations. Because specific information may be lacking on maximum tolerable alteration levels and specific minimum habitat sizes needed to maintain functional ecosystems, the computer program provides a method to select areas that is repeatable and scientifically defensible (Stewart et al. 2003). In virtually all instances when site-selection tools are used, their results are treated as a first approximation for determining priority areas, not the final result. Final site selections are ultimately based on other factors as well, and incorporate expert scientific knowledge to help overcome information gaps and consider socio-economic factors that may not have been included in the MARXAN inputs. Thus, the site-selection program is a decision-support tool.

A MARXAN analysis is generally repeated numerous times, since it is an iterative improvement process. The selected hexagons are accompanied by scores indicating the frequency each hexagon was selected (maximum of 100 for 100 runs). In most cases, low selection scores for selected hexagons correspond to higher alteration levels. In this analysis, each scenario was run 100 times with 1,000,000 iterations per run. The resulting map can show a "peppering" of many small areas if there is no benefit to clustering hexagons. Many small areas are unacceptable as area designations. More enforceable management areas can be found by including a boundary length modifier (BLM) in the selection[1]. A higher BLM encourages selection of larger, more rounded "clusters" of hexagons. The drawback of increasing the BLM is a corresponding increase in total alteration captured by the selections.

NATURAL RESOURCE TARGETS

In using a computerized tool such as MARXAN, the differentiation of appropriate habitats types (NRTs) for selection is vital. Further differentiation of habitat types is needed to ensure that different functions and/or fish assemblages are represented. Not differentiating distinctive habitats may lead to a lack of representation for some important habitat characteristics. As a reminder, the program seeks to capture the amount of each NRT the SHA advisory committee approves/recommends. And the program will seek to find them all in the smallest area possible with least alteration. The program also has a minimum smallest area approved/specified by the advisory committee to make enforceable boundaries. The selected areas are made up of hexagonal grid cells of somewhat arbitrary size. In the case of region #1, the grid cell size was set at 0.5 km^2 (125 acres). A base representation level of 30% was used as the initial value for each NRT, based on the literature. This number was adjusted up or down for each NRT based on rarity, vulnerability, or sensitivity of a habitat, or known or historic losses. For example, SAV is set at 80% due to its sensitivity, vulnerability, and relative importance as a nursery habitat, while soft bottom which is relatively abundant and hardy, is set for 15% or less.

Once the natural resource targets and total alteration layer were assembled, MARXAN was run at the specified representation levels (Table 1). The program was run for three different scenarios, all with initial seeding the shoreline[2]: (Scen1) BLM of 0.01 and full representation levels, (Scen2) BLM of 0.01 and representation levels reduced by one third, and (Scen3) BLM of 0.01 and a stratified reduction in representation levels. The stratified reduction starts with making three categories of the full representation levels: high, medium, and low. The high category was anything >40%, the medium category was 20-40%, and the low category was <20%. The high representation levels were reduced the least (20%), followed by medium (50%), and low (70%). For each scenario, only one variable (BLM or representation level) was changed so comparisons could be made. The committee then reviewed the resulting selections to guide their designation decisions (Maps 2-4).

[1] A boundary length modifier is a program option used to create more aggregated selection of target areas.
[2] Seeded hexagons are included in the first iteration of a MARXAN run

Table 1. List of natural resource targets and representation levels used in the analysis. Scen1 = full representation, Scen2 = reduced representation, and Scen3 = stratified reduction.

CHPP habitats		Natural Resource Targets	Acres/miles	Scen 1	Scen2	Scen3
Polygon map origin (acres)	Wetlands	Estuarine forested wetland (mostly wet)	9,422.47	30%	10%	15%
		Estuarine forested wetland (wet)	13.11	0%	0%	0%
		Freshwater forested wetland (mostly dry)	520,399.51	25%	8%	8%
		Freshwater forested wetland (mostly wet)	392,354.25	40%	13%	20%
		Freshwater forested wetland (wet)	207,048.87	40%	13%	20%
		Freshwater marsh (mostly dry)	10,284.19	25%	8%	8%
		Freshwater marsh (mostly wet)	4,470.92	40%	13%	20%
		Freshwater marsh (wet)	2,297.37	40%	13%	20%
		Salt/brackish marsh	56,305.92	30%	10%	15%
	SAV	High salinity SAV	3,201.79	80%	27%	64%
		Low salinity SAV	22,193.62	80%	27%	64%
		SAV in shell bottom	39	90%	30%	72%
	Shell bottom	Intertidal shell bottom (high density)	16.01	75%	25%	60%
		Intertidal shell bottom (low density)	23.68	30%	10%	15%
		Subtidal shell bottom (high density)	427.22	75%	25%	60%
		Subtidal shell bottom (low density)	75.46	30%	10%	15%
	Soft bottom	Estuarine soft bottom (>6 ft)	395,167.71	10%	3%	3%
		Estuarine soft bottom (0-3ft)	97,749.29	30%	10%	15%
		Estuarine soft bottom (3-6ft)	113,764.96	20%	7%	6%
		Estuarine soft bottom (ND)	9,027.95	30%	10%	15%
		Intertidal estuarine soft bottom	86.29	30%	10%	15%
		Intertidal marine soft bottom	2,533.32	30%	10%	15%
		Lacustrine soft bottom (ND)	21,743.94	15%	5%	5%
		Marine soft bottom (>6 ft)	191,840.80	10%	3%	3%
		Marine soft bottom (0-3ft)	6,041.33	30%	10%	15%
		Marine soft bottom (3-6ft)	7,446.40	20%	7%	6%
		Marine soft bottom (ND)	13.12	0%	0%	0%
		Non-wetland shore	20.28	0%	0%	0%
		Pond soft bottom (ND)	6,900.73	10%	3%	3%
		Riverine soft bottom (>6 ft)	23,724.36	10%	3%	3%
		Riverine soft bottom (0-3ft)	2,703.33	30%	10%	15%
		Riverine soft bottom (3-6ft)	2,283.59	20%	7%	6%
		Riverine soft bottom (ND) – lower	25,376.86	30%	10%	15%
		Riverine soft bottom (ND) – middle	1,260.18	20%	7%	6%
		Riverine soft bottom (ND) – upper	585.41	10%	3%	3%
	Hard bottom	Riverine hard bottom	1,116.28	100%	100%	100%
	TOTAL polygon area and representation level		2,137,959.50	26%	8%	11%
	Wetlands	Wetland edge	3,532.62	40%	13%	20%
	Soft bottom	non-wetland shoreline	1,640.23	20%	7%	6%
	Water column	Streams (high elevation)	1,550.50	10%	3%	3%
		Streams (low elevation)	7,913.48	30%	10%	15%
		Streams (middle elevation)	3,519.22	20%	7%	6%
	Hard bottom	Hard bottom (possible)	12.19	75%	25%	60%
	TOTAL line distance and representation level		18,168.25	27%	9%	12%

NRT descriptions

Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation beds in Region 1 were mapped by aerial photography interpretation. The SAV target is defined by the degree of correspondence between submerged aquatic vegetation verified on the ground and visually similar areas on the imagery. The various sources range in currency from the early 1980's to the very recent (Carroway and Priddy 1983; Ferguson and Wood 1994; ECSU 2002-2003-2006; DWQ 1998; DWQ 2005-2006-2007; DMF 1988-present). With data up to 25 years old, significant changes in the distribution of SAV beds are likely to occur. Furthermore, the distribution of grass is likely more extensive than aerial observations suggest. For example, the growth of narrow fringing SAV beds and beds growing in organic stained water is difficult to discern from aerial photography (S. Chappell/DMF and J. Greene/DWQ, personal observation). So the presence of SAV is not wholly represented by the mapping data.

The presence of SAV is a general indicator of less than eutrophic conditions. 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. The distribution of mapped SAV was further divided into low and high salinity beds. Whereas all SAV beds provide similar ecological services, the two types encompass different fish assemblages. The dividing line between low and high salinity beds was set at the >15 ppt boundary during the high salinity time period (summer). Low salinity grasses occur from 0 and 10 ppt, and high salinity grasses (shoal grass, eel grass) generally occur at >10 ppt salinity (Street et al. 2005). However, the map used to separate salinity zones was not divided into these intervals. The closest interval was the mid-point between freshwater and full strength sea water (0-30ppt/2=15ppt). The boundary used (15 ppt) helps capture the fluctuating boundary of both low and high salinity areas.

Because SAV habitat is considered highly valuable fish habitat, is vulnerable to land use changes, and is relatively less abundant than other fish habitats, a high percentage (80%) was selected in the full representation. The stratified random and reduced scenarios targeted 64% and 27% of SAV, respectively

Shell bottom

Shell bottoms in Region 1 were mapped from interpolated transect data collected by the DMF Bottom Mapping Program (DMF 1988-present). The source data ranges from 1989 to 2006, depending on the specific location or area. The shell bottom target is defined where at least 30% of the bottom is covered by living or dead shellfish (typically oysters) in water generally less than 6 feet deep. Basic shell bottom subtypes include intertidal and subtidal; distinctions made by the Bottom Mapping Program. To capture different functional characteristics among shell bottom types, we further differentiated the habitat based on density of living shellfish. For high-density beds, we used the MFC's definition of shellfish lease producing area (1 shellfish/m^2) to set the minimum threshold. Low-density beds are basically shell hash or clam bed areas.

Because high-density shell bottom is considered rare and highly valued fish habitat in Region 1, it was given a high representation level (75%) whereas low-density shell bottom (shell hash or clam beds) was given the initial 30% representation. The stratified random and reduced scenarios targeted 60% and 20% of the high density shell bottom, respectively. The low density beds were targeted at 15% and 10%, respectively.

Adjoining wetlands

There were two sources of wetland maps: National Wetland Inventory (1981-1982-1983) and N.C. Division of Coastal Management (1994). The National Wetland Inventory (NWI) maps, Natural Resource Conservation Service digital soil surveys, satellite imagery (1994), and hydrography maps were used to create the Division of Coastal Management (DCM) wetland coverage. The NWI maps were based on aerial photo interpretations using a complex habitat classification system described in Cowardin et al. (1979) (also see Appendix C). The DCM wetlands data are considered superior to the NWI maps due to their simplicity in practical application. However, the DCM data is not available for Virginia portions of the region. Therefore, a modified and simplified NWI classification was used for covering the entire area of Region 1. But the DCM data was still used to fill minor gaps in the NWI data in North Carolina.

The process used to identify adjoining wetlands involved several steps. First, adjacent wetland polygons were combined to form contiguous polygons. These contiguous polygons encompassed water regimes ranging from temporarily flooded/saturated to permanently flooded. Next, we included only aggregate polygons that intersected the network of streams and water bodies used in this analysis (see later sections) – these were considered adjoining wetland targets. The following types of wetlands were pulled from the NWI data.

Freshwater forested wetlands

This classification corresponded to the NWI's palustrine system and the forested or shrub/scrub class. The palustrine system included both riverine and flat/depressional hydrogeomorphic categories used by DCM. The NWI riverine system included primarily the river itself. The NWI water regime modifiers were used to further classify freshwater forested wetlands into 3 types: mostly dry, mostly wet, and wet. Mostly dry wetlands included the majority of pocosins, bottomland hardwood forests and headwater wetlands in the region, as defined in Sutter (1999). The water regimes used for this classification were temporarily flooded and saturated (see Appendix C). Mostly wet and wet forested wetlands included the majority of riverine swamp forests in the region. The water regimes used for the "mostly wet" classification were all seasonally flooded. Semi-permanently and permanently flooded water regimes were used for the "wet" classification. The reason for the different water regime classification was differing fish use and response to sea level rise. Permanently flooded forests are used by swamp fish year-round. These areas can get very low in dissolved oxygen and pH. Seasonally flooded wetlands are used during periods of high water for enhanced foraging opportunities, spawning and attachment of eggs for some anadromous species (i.e., river herring). Mostly dry wetlands are generally not used by fish, but could transition into fish habitat wetlands with rising sea levels.

Seasonal (mostly wet) or semi-permanently (wet) flooded Freshwater forested wetlands were given a slightly higher representation level (40%) due to their importance to anadromous species. Forested wetlands that were intermittently flooded were given a slightly lower representation level (25%) due to infrequent fish use. The stratified reduction and reduced scenarios targeted 20% and 13% of the seasonal and semi-permanently flooded freshwater forested wetlands, respectively. In both stratified and reduced scenarios, the intermittently flooded (mostly dry) freshwater forested wetlands were targeted at 8%.

Freshwater marsh

This classification corresponds to the NWI's riverine, palustrine or lacustrine system and the emergent vegetation class. The NWI water regime modifiers were the same applied to forested wetlands. The freshwater marsh target corresponds directly to the DCM freshwater marsh class. The representation levels for freshwater marsh were identical to freshwater forested wetlands.

Estuarine forested wetlands

This classification corresponds to the NWI's estuarine system and the forested or shrub/scrub class. The water regimes for tidal estuarine systems were different than non-tidal freshwater systems. Mostly dry estuarine wetlands had the modifier for temporarily flooded (none present or considered riparian in the region). Mostly wet estuarine wetlands were irregularly or seasonally flooded. The wind tidal systems in Region 1 are irregularly flooded. Mostly wet estuarine forested wetlands included the majority of estuarine shrub/scrub wetland classified on the DCM maps. Mostly wet estuarine wetlands were given the base representation level of 30% in the full scenario. The stratified reduction and reduced scenarios targeted 15% and 10% of the estuarine forested wetlands, respectively.

Salt/brackish marsh

This classification corresponds to the NWI's estuarine system and emergent vegetation class. The water regimes were nearly all irregularly flooded due to wind tides in the region. However, salt marshes in the eastern subregion of the analysis are likely influenced by lunar tides. But we did not separate brackish and salt marsh because the NWI oligohaline modifier was inconsistently applied. High and low marsh were also not distinguished on the NWI data. The salt/brackish marsh target corresponds directly to the DCM salt/brackish marsh class. Despite their relative importance, salt-brackish marsh was given the initial representation level because it receives a relatively high degree of protection already. Thus, the stratified reduction and reduced scenarios targeted 15% and 10% of salt brackish marsh, respectively.

Wetland edge

This target consists of the linear intersection of wetlands and deepwater habitats including soft bottom, SAV, shell bottom, and hard bottom. The wetland edge target does not distinguish between marsh and forested edges. The inclusion of wetland edges was meant to minimize the selection of large areas of interior wetland (regardless of type), as well as capture an important ecotone within aquatic systems. Wetland edge was given a slightly higher representation level (40%) because of that importance. In the stratified reduction and reduced scenarios, wetland edge was targeted at 20% and 13%, respectively.

Soft bottom

This target was developed from a combination of DMF jurisdictional waters and NWI deepwater habitats. The DMF jurisdictional waters coverage (FWJ) is a more detailed delineation of the mean high water line (contains wetlands in tidal areas) than the NWI data. The "deepwater" habitats from NWI included unconsolidated bottoms and aquatic beds. Open waters indicated on the FWJ coverage were combined with NWI deepwater habitats to form a continuous coverage. Basically, soft bottom occurred wherever there was no SAV or shell bottom.

The soft bottom categories were further classified by system and depth category. The depth categories were 0-3ft, 3-6ft, >6 ft and no depth. These distinctions are important because they correspond to major spatial differences in ecological function (i.e., shallow water nurseries). Consequently, shallow soft bottom NRTs were given the base representation level, whereas deep soft bottom NRTs were given a lower representation level. This data was digitized from NOAA bathymetric charts (http://nauticalcharts.noaa.gov/mcd/Raster/Index.htm). The "no depth" category was generally specified for channel-like hydrographic features adjoining more open waters, or where the bathymetric charts indicated no data. The delineation is valid where channel-like features are actually >3 ft deep. Unfortunately, these delineations may not have been consistently or completely applied. The systems used for classification included riverine, lacustrine (lakes), palustrine (ponds), estuarine, and marine.

- **Riverine** systems were separated from low salinity estuarine systems based on a linear or meandering morphology and a substantial (unditched) drainage network upstream. Linear or meandering waters bordering estuarine wetlands without a substantial drainage network (i.e., tidal creeks) were classified as estuarine. However, linear waters without a substantial drainage (i.e., canals) and bordering freshwater wetlands were also classified as riverine. Classifying drainages as substantial was consistently applied, but the criteria were subjective.
- The **marine** system includes subtidal and intertidal waters of the coastal ocean and Oregon Inlet hydrologic unit.
- The **estuarine** system includes all open waters and intertidal flats between riverine and marine systems. The estuarine system also includes pond-like features surrounded by estuarine wetlands. Ideally, there should be a distinction made between tidal creeks, isolated marsh pools, and estuarine open waters. Large tidal creeks, isolated marsh pools, and some estuarine open waters are currently lumped together. The no depth estuarine soft bottom NRT was given the base representation level due to the presence of tidal creeks.
- **Lacustrine** systems (lakes) were classified as such by NWI. They were distinguished from

ponds using a size threshold of 15 acres. Only lakes connected to riverine or estuarine systems by linear water features (described later) were included. However, "connected" was loosely defined to include features within 30 meters of a contiguous water feature. Lakes were given a lower representation level because of their relatively low use by anadromous fish.

- **Ponds** were classified by NWI as Palustrine systems with an unconsolidated bottom. They were distinguished from lakes using a size threshold (<15 acres). Only ponds connected to riverine or estuarine systems by linear water features (described later) were included. Again, "connected" was loosely defined to include features within 30 meters of a contiguous water feature. Ponds were given a lower representation level because of their relatively low use by anadromous fish.

Estuarine and marine intertidal flats are below the mean high water line indicated on the fishing water jurisdiction coverage. Estuarine intertidal flats were classified by NWI as unconsolidated shores within the estuarine/intertidal system/subsystem. Major marine intertidal flats were delineated from 1998 aerial photographs of the Oregon Inlet area. The NWI data was not used because it omitted some well-known flats in the area. A narrow band of intertidal habitat along the Atlantic Ocean was assumed. Although intertidal flats are rare and important habitats in Region 1, they were given the base representation level due to questionable mapping accuracy.

Non-wetland edges are also included in the category of soft bottom. This linear target was created from the intersection of uplands and deep-water features. There were also small areas of unconsolidated shore in riverine and palustrine systems. These small areas created the need for a "non-wetland shore" target. Non-wetland shores were given a slightly lower representation level due to their lack of structure.

Hard bottom

This linear target was taken directly from the Southeast Area Monitoring and Assessment Program's reef-dependent fish collections up until the late 1990's (SEAMAP 2001). The gear used to collect the fish varied such that a polygon feature could not be created. Therefore, the line indicating hard bottom represents only a probability of proximity to hard bottom; the probability determined by a species affinity for hard bottom. Due to the rarity and importance of this habitat, a high representation level was chosen.

There is also hard bottom (i.e., rocky outcroppings) present in middle elevation sections of riverine soft bottom habitat. The specific location of the rocky outcrops was specified by WRC staff (Chad Thomas, pers. comm.. January 2008) for inclusion in the MARXAN selections. Due to the rarity and extreme importance of these areas, a representation level of 100% was chosen.

Water column (linear water features)

Small creeks and streams were represented using 1:100,000 scale data from the National Hydrologic Dataset (NHD). An NHD dataset was used to represent a connected network of stream channels "under" polygon water features. The streams were clipped out of the open water features to leave a continuum from linear to polygon water features. Finer scale NHD data was not available for the entire region and the coarser scale data represented larger streams that fish more frequently use.

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

The representation levels for streams varied according to elevation. The highest elevation streams were given the lowest representation levels due to relatively low use by anadromous species. The lowest elevation streams were given the base representation level.

ALTERATION FACTORS

The subset of alteration factors used in the analysis are listed and described in Table 3. Many other factors were considered, but could not be included for various reasons. Among them were DWQ use support ratings, 2006 land cover data, stormwater outfalls, surface water intakes, marinas, shoreline development, beach nourishment, and animals operations/spray fields.

- DWQ use support ratings were not used because they only applied to the best use (i.e., water supply) and we needed only aquatic life use support. So if something was impaired for water supply, we could not assume it was also impaired for aquatic life.
- 2006 land cover data will not be available until 2009 (NLCD representative, pers. com., January 2008), and there are no other sources of classified data currently available.
- Stormwater outfall maps from DWQ and DEH-SS were incomplete for the region.
- NPDES sites covered major surface water intakes.
- GIS data for marinas in the area is dated and new information is incomplete.
- GIS data on recent shoreline development is currently nonexistent.
- No beach nourishment has occurred in the region.
- GIS data on animal operations in the area was out of date.

Factors were also evaluated for duplication with other factors. For example, one should not include multiple factors indicating the same water quality impacts from development. This would be exaggerating the impact of development, relative to other factors. Alternatively, one could average the impact of similar alteration factors, if the duplicate factors are available. But this was not done for the initial MARXAN selections.

Table 3. List of alteration factors used for Region 1 Strategic Habitat Area assessment. Note: Water based includes factors that occur directly to a NRT and are applied to the portion that overlays that target within the hexagon; land based refers to factors that effect the NRT indirectly and are applied to all hexagons within the same HU; point based includes factors whose effect is applied to upstream or downstream HU(s).

Factor type	Factor	Alteration type (feature affected)	Source
Hydrology	Culverts (partial obstructions)	point/water-based	DOT database (2003), Moser and Terra (1999), Collier and Odum (1989) + possible culverts from intersection of roads (1998) and streams where bridges are absent.
	Storm gates and locks (partial obstructions)	point/water-based	Collier and Odum (1989) - storm gates and locks (included lock on Dismal Swamp canal only)
	Impoundments (fully obstructed)	point/water-based	DWR database (2003; some removed), Collier and Odum (1989), and NWI wetland modifier (1994) - diked/impounded.
	Channelized streams	water-based	Used maps of drainage projects in the area from NRCS
	Dredge channels	water-based	COE dredging (2003) - doesn't include DWR or private dredging (i.e., Sandy Point)
	Drained wetlands	water-based	NWI wetland modifier (partially drained)
	Ditched streams	water-based	NHD data - ditched stream type
	Canals and boat basins	water-based	Obvious channels and boat basins suggested on shoreline coverage (DMF/WRC fishing water jurisdiction)
Land use & water quality	Industrial waste pond	water-based	Indicated on NC Atlas and Gazetteer 1997
	NPDES sites	land-based	DWQ 2006 and VDEQ 2004 - Various types and quantities of discharge (WWTPs, WTPs, industrial discharges, reverse osmosis plants, schools, military installations, etc.)
	%Developed	land-based	National Land Cover dataset (2001) - Developed and barren classes
	%Agriculture	land-based	National Land Cover dataset (2001) - Cropland and pastureland classes
	Development change	land-based	NCDWQ stormwater permits and VDEQ water protection permits (2002-2006)
Physical	Wetlands lost to development	water-based	Overlay wetlands with 2001 developed land use classification
	Wetland lost to agriculture	water-based	Overlay (forested) wetlands with 2001 cropland, pastureland, and barren land use classification
	Riparian upland development	water-based	Overlay riparian uplands with 2001 developed land use classifications
	Riparian upland agriculture	water-based	Overlap riparian uplands with 2001 cropland, pastureland, and barren land use classifications
	Bottom disturbing fishing gear	water-based	DMF coverages for trawling, oyster dredging, and crab dredging

Factor descriptions

Hydrology alterations

Partial obstructions (locks, culverts)

This factor currently includes only natural resource targets upstream from the lock on the Dismal Swamp canal. In future analyses, we hope to include additional obstructions based on culvert locations and characteristics. The NRTs upstream of Dismal Swamp canal were encompassed using 12-digit USGS hydrologic units.

Impoundments

Impounded waters include all natural resource targets upstream from documented dam locations. The data sources for dam locations were DWR records (2003, some removed), and Collier and Odum (1989). The NWI modifier for diked/impounded will be included in future MARXAN runs. The location of fish passage devices should be included and reviewed by appropriate committee members. Fish passage devices could make previously inaccessible waters partially accessible.

Channelized streams

Channelized streams are natural streambeds that were artificially straightened to enhance drainage and/or navigation. They differ from canals where there's an original streambed. In other words, canals typically have little or no natural drainage. The specific location of channelization projects was digitized from Natural Resource Conservation Service blueprints (Wayne Howell, pers. comm., January 2008).

Dredged channels

This factor includes areas dredged by COE on a regular basis. The source data originated from 2003. The map does not include channels dredged by the DWR or private channels dredged for deep-water access. The missed areas may be associated with canals and boat basins.

Drained wetlands

Partially drained wetland areas were taken from NWI and DCM wetland modifiers. These data sources originated from the early 1990's, therefore this data doesn't include drainage projects that have occurred since that time. However, drainage projects in riparian wetlands have generally not been allowed since then.

Ditched streams

Ditched lines were classified as such on the NHD data. The classifications were based an obvious linear and angular morphology. Therefore, natural streams that happen to be straight could be included.

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 drainage (short, water access canals or boat basins). Some of the delineated boat basins could also be associated with marinas.

Water Quality and land use alterations

Industrial waste ponds

This alteration factor was added to cover a large industrial waste pond located very close to other natural resource targets along a tributary of the Roanoke River. The waste pond was shown on the 1997 North Carolina Atlas and Gazetteer (Delorme 1997). Another industrial waste pond along the upper Roanoke

River was removed from the natural resource targets.

NPDES sites

This factor was derived from NPDES sites locations provided by NCDWQ and VDEQ. There are various types of discharge represented by the NPDES, some more altering than others. But it is difficult to determine the area of influence for a point source. We therefore decided to assign NPDES sites to appropriate hydrologic units for counting, as a measure of alteration. The maximum number of major or minor NPDES within hydrologic units was used in calculating the proportion impacted. Note that major and minor NPDES were given different impact severities relative to habitat types (Table 3).

Agricultural land use

This factor was extracted from the 2001 National Land Cover Dataset (cropland and pasture classifications). The total area of cropland within each 12-digit USGS hydrologic unit (HU) was calculated and applied to corresponding natural resource targets. A greater proportion of cropland within an HU suggests higher nutrient and chemical loadings from non-point agricultural sources.

Developed land use

This factor was extracted from the 2001 National Land Cover Dataset (developed classifications). The total area of developed land-use within each 12-digit USGS hydrologic unit was calculated and applied to corresponding natural resource targets. A greater proportion of development within an HU suggests higher nutrient and chemical loadings from non-point development sources.

Development change

In lieu of 2006 land cover classification (presently unavailable), we decided to get stormwater permit records for a period after 2001 land cover classifications. The data were gathered from the NCDWQ and VDEQ for 2002-2006. The data were corrected for obvious misplacement of points (i.e., wrong county) and duplication. Then counts of permits were applied to hydrologic units, similar to NPDES sites.

Physical disturbance

Trawling and dredging

Areas open to trawling were located in subtidal areas >3ft deep outside of no trawl areas. The no trawling area coverage was created by DMF in accordance with 2004 MFC rules. The other bottom disturbing gears included were crab and oyster dredges, also based on 2004 MFC rules. The extent of trawling and dredging areas in this region has not changed significantly since 2004.

Converted wetlands

This alteration factor was created by comparing wetland areas from the early 1990's to land use classifications from 2001 (30m resolution). The resulting maps show wetland areas that are now in some form of upland development, cropland, pastureland, or barren classification. The classifications for development included low, medium, high, and open space. Cropland was only compared to forested wetlands due to frequent confusion between salt marsh and cropland. Converted wetlands accurately reflect large shoreline developments where the shoreline has not greatly receded.

Converted uplands

This factor is specifically related to land uses within riparian upland areas. The land uses compared to converted wetlands were also used for converted uplands. And like converted wetlands, converted uplands accurately reflect large shoreline developments where the shoreline has not greatly receded.

Cumulative Impacts (Total Alteration)

The NRTs were grouped into categories for showing their coincidence with alteration factors. The groupings were based on similar impacts ratings. For example, all wetland types are affected similarly by ditching and drainage (relative to other NRTs). Therefore, all wetlands should be grouped for applying alteration factors. However, there were linear wetland features and polygon wetland features. In order to apply the equations presented in the SHA report, the linear features were converted into narrow polygon features (Figure 1). This conversion is also consistent with reality, as lines are of infinitesimal width. This conversion was also done for linear water features. The NRT groupings are listed in Table 2 and described below:

- Riparian wetland – Line features that were converted to polygons using a buffer 15 meters landward from wetland shorelines.
- Interior wetland – Polygon features >15 meters from wetland shoreline.
- SAV – All categories of SAV
- Shell bottom – All categories of shell bottom
- Soft bottom – All categories of soft bottom, except riverine. This category represents soft bottom under standing water conditions.
- Riparian upland – Line features that were converted to polygons using a buffer 15 meters landward from non-wetland shorelines.
- 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.
- Creeks/rivers – Polygon water column features for riverine soft bottom NRTs. This category represents soft bottom under flowing water conditions.

Figure 1. Example hexagon showing some habitat types for alteration (labeled). Dark green = riparian wetland, light green = interior wetland, dark blue = streams, light blue = creeks/rivers.

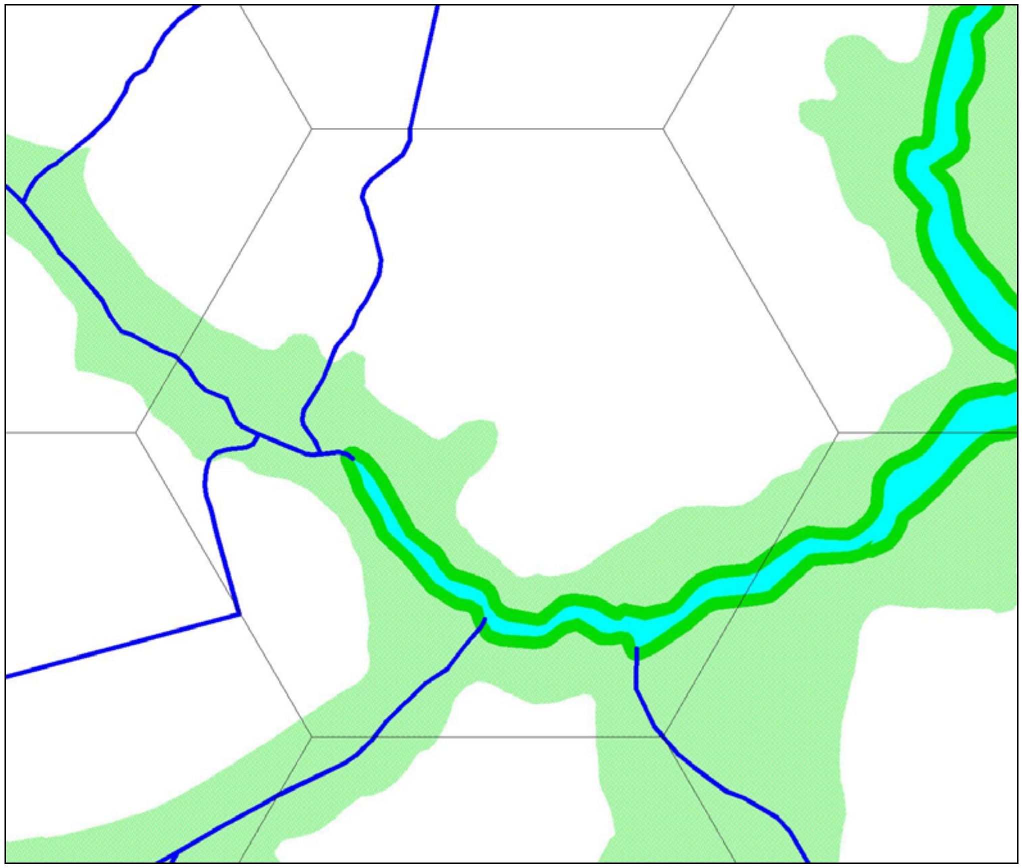


Table 2. Summary statistics by region and hexagon for habitat types used in determining alteration.

Stats (acres)		Region total	Hex avg.	Hex max.
Polygon origin	**Interior wetland**	1,170,344.37	42.007	124.29
	Creek/river	57,045.22	20.865	124.29
	SAV	25,439.01	22.612	124.29
	Shell bottom	543.963	3.465	44.538
	Soft bottom	852,346.20	71.201	124.29
Line origin	**Streams**	25,799.44	1.081	7.494
	Riparian upland	9,934.40	1.725	24.042
	Riparian wetland	20,690.17	3.165	24.579
	TOTAL	2,162,142.77		

Table 3 shows the alteration factor rating for NRT groups based on CHPP habitat types. The factor ratings were guided by a modified version of a similar table in Street et al. 2005. We also used the spatial representation and potential overlap of natural resource targets and alteration factors to set the factor ratings. In other words, if a factor did not overlap with a natural resource target, it was given an X rating.

Thus, multiple factors within a hexagon contribute to cumulative impacts quantitatively. We then created a total alteration layer (Map 5) using the formulas and technique described in the guiding document (Appendix D). Basically, each hexagon of the total alteration layer is given a score based on the sum of the relative extent of each habitat multiplied by portion impacted and the impact rating. These calculations were queried from GIS dbase tables exported to an Access database.

Table 3. Alteration factor ratings used in the current MARXAN analysis.

	Hydrology							Water quality						Physical				
CHPP habitat (NRT groupings)	Culvert obstructed	Lock obstructed	Impounded	Channelized streams	Dredged channels	Ditched/drained	Canals & boat basin	Industrial waste pond	Major NPDES	Minor NPDES	Developed land-use	Agricultural land-use	Development change	Bottom disturbing fishing gear	Wetlands lost to development[5]	Wetlands lost to agriculture[6]	Riparian upland development	Riparian upland agriculture
Riparian wetlands[1]	0.5	1	2	2	X	X	X	X	X	X	0	0	1	X	3	2	X	X
Interior wetlands[2]	0.5	1	2	X	X	2	X	X	X	X	0	0	2	X	2	1	X	X
SAV	0.5	1	2	X	3	X	2	X	2	1	2	2	2	2	X	X	X	X
Shell bottom	X	X	X	X	3	X	1	X	1	1	2	1	2	2	X	X	X	X
Riparian uplands[3]	0.5	1	2	1	X	X	X	X	X	X	1	1	1	X	X	X	2	1
Soft bottom	0.5	1	2	X	1	X	1	3	2	1	1	1	1	1	X	X	X	X
Water column - small streams[4]	0.5	1	2	1	X	2	X	X	3	2	2	2	3	X	X	X	X	X
Water column - creeks, rivers	X	1	2	1	X	X	1	X	2	1	2	2	1	X	X	X	X	X

[1] 15 meter landward buffer from wetland edge

[2] Wetlands >15 meters from wetland edge

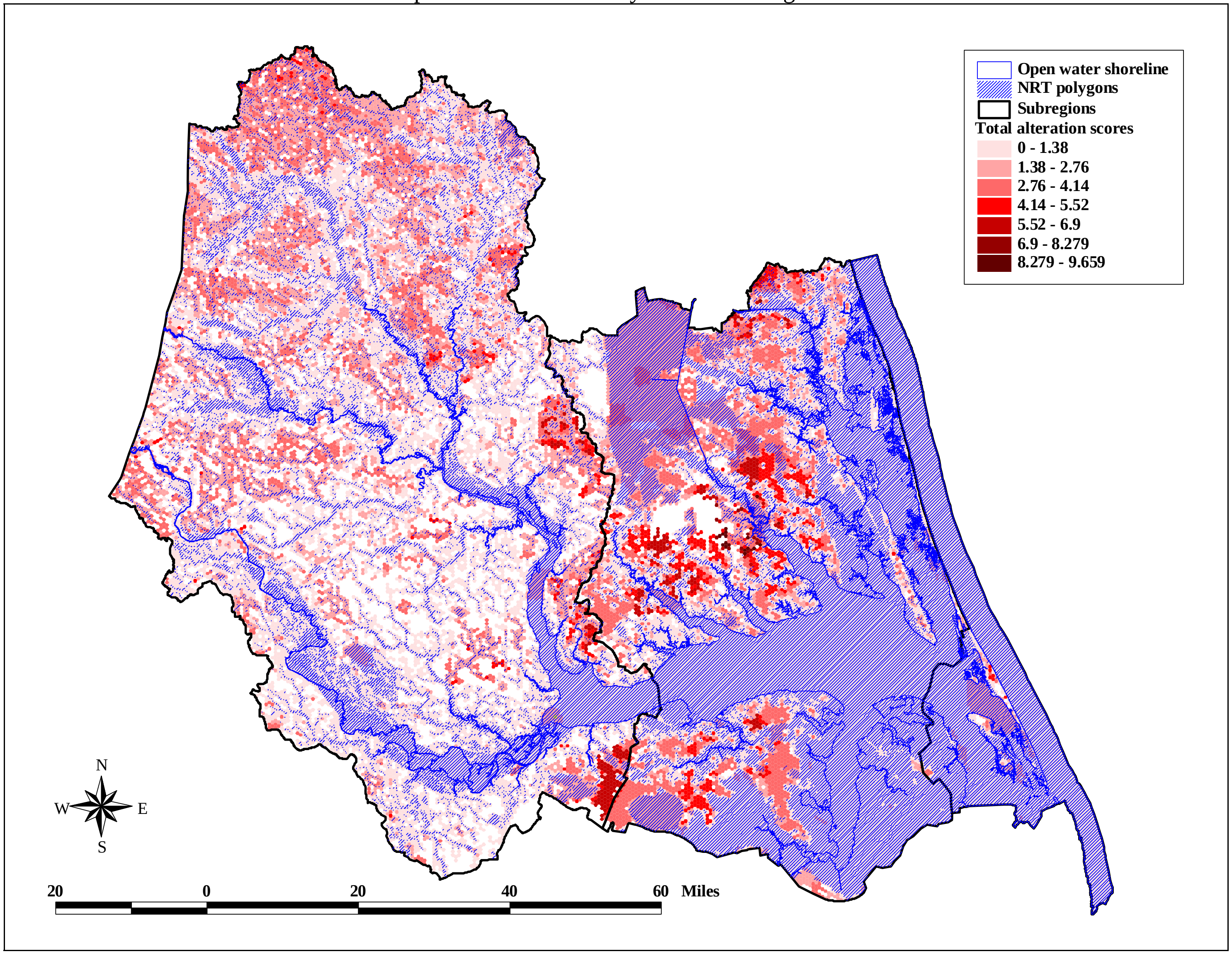
[3] 15 meter landward buffer from non-wetland shoreline

[4] 2.5 meter buffer around stream

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

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

Map 5. Total alteration layer for SHA Region 1.



SITE SELECTION TOOL RESULTS

The MARXAN program took approximately 20 hours to run each scenario. The results are presented in Tables 4 and 5 below and later in map format. It is important to note here that not all the representation levels were exactly met; there were some NRTs selections that greatly exceeded their target representation (Table 5). For example, forested wetlands (wet and mostly dry) and soft bottom (>6 ft) were disproportionately represented because of their widespread distribution and co-occurrence with other NRTs.

The full representation captured the most habitat area and the second highest alteration. The reduced representation captured the least habitat and highest alteration. The stratified reduction representation captured an intermediate amount of habitat with the least alteration. Based on the percent of habitat area and lowest alteration captured, the best scenario was therefore the stratified reduction. The committee decided to work from the stratified reduction scenario, corroborating and modifying computer selections as needed.

Table 4. Summary statistics for MARXAN scenarios run.

Scenario	Acres selected (% of total)	Avg. alteration (in)	Avg. alteration (out)
0.01 BLM, full rep.	664,922.78 (31)	0.7977	1.3180
0.01 BLM, reduced rep.	251,678.32 (12)	0.8165	1.2376
0.01 BLM Stratified reduction	456,209.31 (21)	0.6639	1.2904

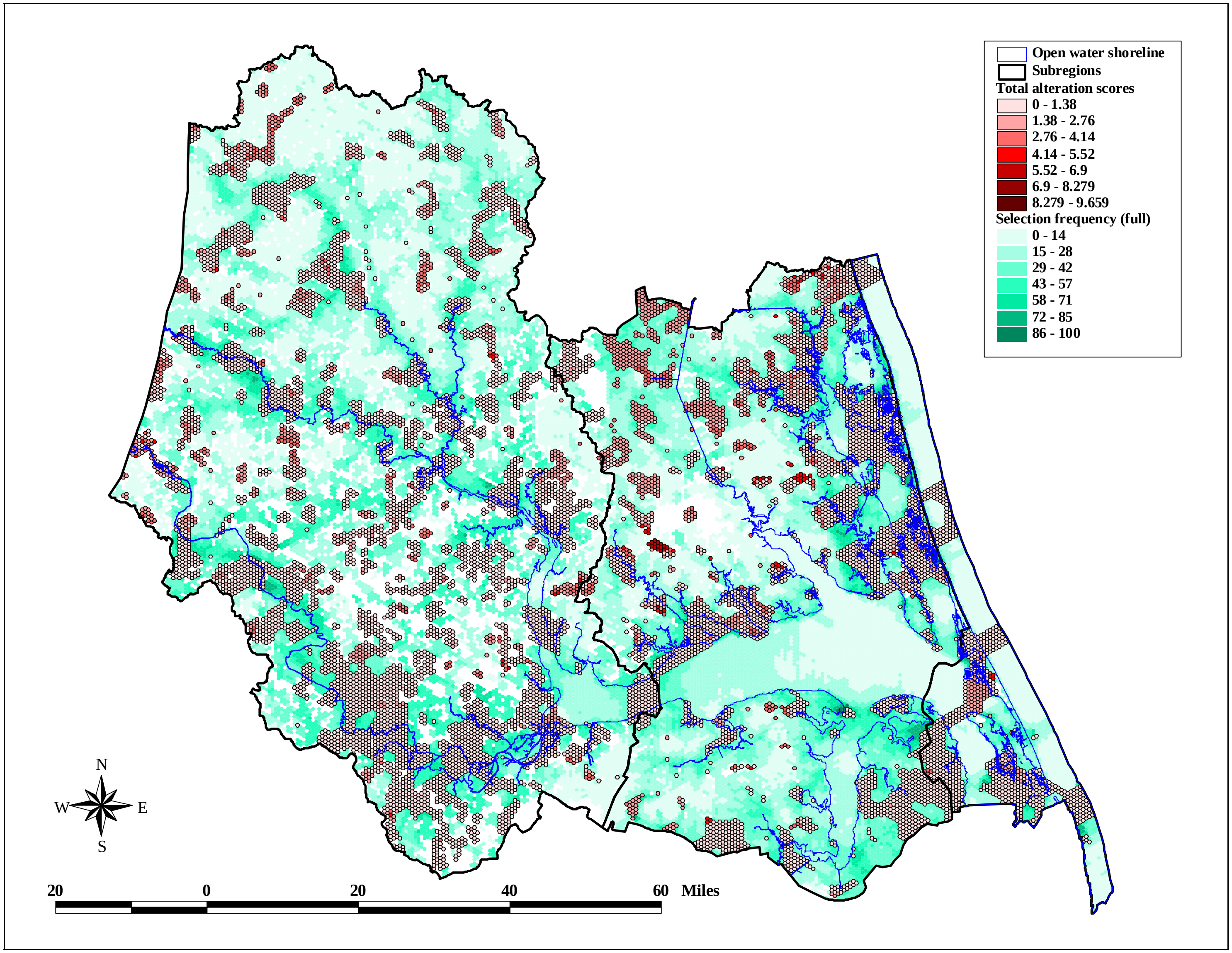
Table 5. List of natural resource targets and representation levels achieved in the stratified reduction scenario.

Feature type	CHPP Habitats	Natural Resource Targets	Acres/miles Targeted	Acres/miles Selected	Difference
Polygon map origin (acres)	Wetlands	Estuarine forested wetland (mostly wet)	1,413.37	1413.37	0.00
		Estuarine forested wetland (wet)	0.00	0.00	0.00
		Freshwater forested wetland (mostly dry)	39,029.96	118,286.2	+79,256.27
		Freshwater forested wetland (mostly wet)	78,470.85	78,470.92	+0.07
		Freshwater forested wetland (wet)	41,409.77	62,693.28	+21,283.51
		Freshwater marsh (mostly dry)	771.31	3,459.75	+2,688.44
		Freshwater marsh (mostly wet)	894.18	895.02	+0.84
		Freshwater marsh (wet)	459.47	459.73	+0.26
		Salt/brackish marsh	8,445.89	1,7362.1	+8,916.21
	SAV	High salinity SAV	2,049.15	2,051.28	+2.13
		Low salinity SAV	14,203.92	14,204.49	+0.57
		SAV in shell bottom	28.08	36.17	+8.09
	Shell bottom	Intertidal shell bottom (high density)	9.61	9.63	+0.02
		Intertidal shell bottom (low density)	3.55	3.92	+0.37
		Subtidal shell bottom (high density)	256.33	256.36	+0.03
		Subtidal shell bottom (low density)	11.32	23.01	+11.69
	Soft bottom	Estuarine soft bottom (>6 ft)	11,855.03	47,858.48	+36,003.45
		Estuarine soft bottom (0-3ft)	14,662.39	27,916.51	+13,254.12
		Estuarine soft bottom (3-6ft)	6,825.90	24,909.9	+18,084.00
		Estuarine soft bottom (ND)	1,354.19	2,359.33	+1,005.14
		Intertidal estuarine soft bottom	12.94	72.86	+59.92
		Intertidal marine soft bottom	380.00	388.39	+8.39
		Lacustrine soft bottom (ND)	978.48	1,750.06	+771.58
		Marine soft bottom (>6 ft)	5,755.22	24,659.02	+18,903.80
		Marine soft bottom (0-3ft)	906.20	1,559.22	+653.02
		Marine soft bottom (3-6ft)	446.78	1,311.28	+864.50
		Marine soft bottom (ND)	0.00	0.28	+0.28
		Non-wetland shore	0.00	1.94	+1.94
		Pond soft bottom (ND)	207.02	775.93	+568.91
		Riverine soft bottom (>6 ft)	711.73	8,676.49	+7964.76
		Riverine soft bottom (0-3ft)	405.50	892.23	+486.73
		Riverine soft bottom (3-6ft)	137.02	937.74	+800.72
		Riverine soft bottom (ND) – lower	3,806.53	7,338.41	+3531.88
		Riverine soft bottom (ND) – middle	75.61	376.59	+300.98
		Riverine soft bottom (ND) – upper	17.56	83.78	+66.22
	Hard bottom	Riverine hard bottom	1,116.28	1,116.03	-0.25
	TOTAL polygon area		237,111.16	452,609.70	+215,498.60
Line map origin (miles)	Hard bottom	Hard bottom (possible)	7.31	7.42	+0.11
	Wetlands	Wetland edge	706.52	1,108.01	+401.49
	Riparian uplands	non-wetland shoreline	98.41	323.24	+224.83
	Water column	Streams (high elevation)	46.52	161.14	+114.62
		Streams (low elevation)	1,187.02	1,187.04	+0.013
		Streams (middle elevation)	211.15	568.82	+357.66
	TOTAL line distance		2,256.942	3,355.66	+1,098.72

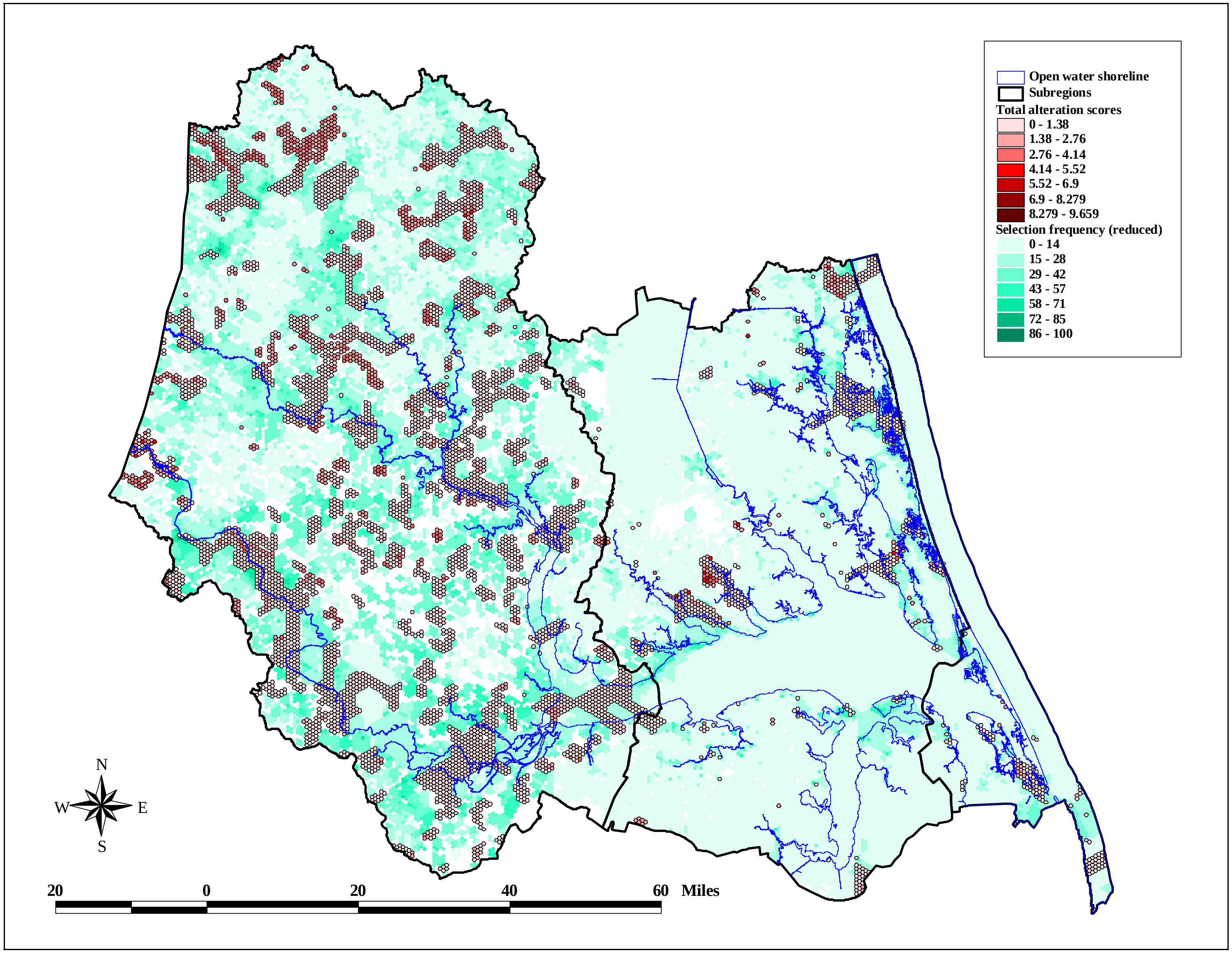
MAPS OF SCENARIOS EXAMINED

Maps 6-8 show MARXAN selection for each scenario classified by alteration and overlaid with selection frequency (blue-green color scale).

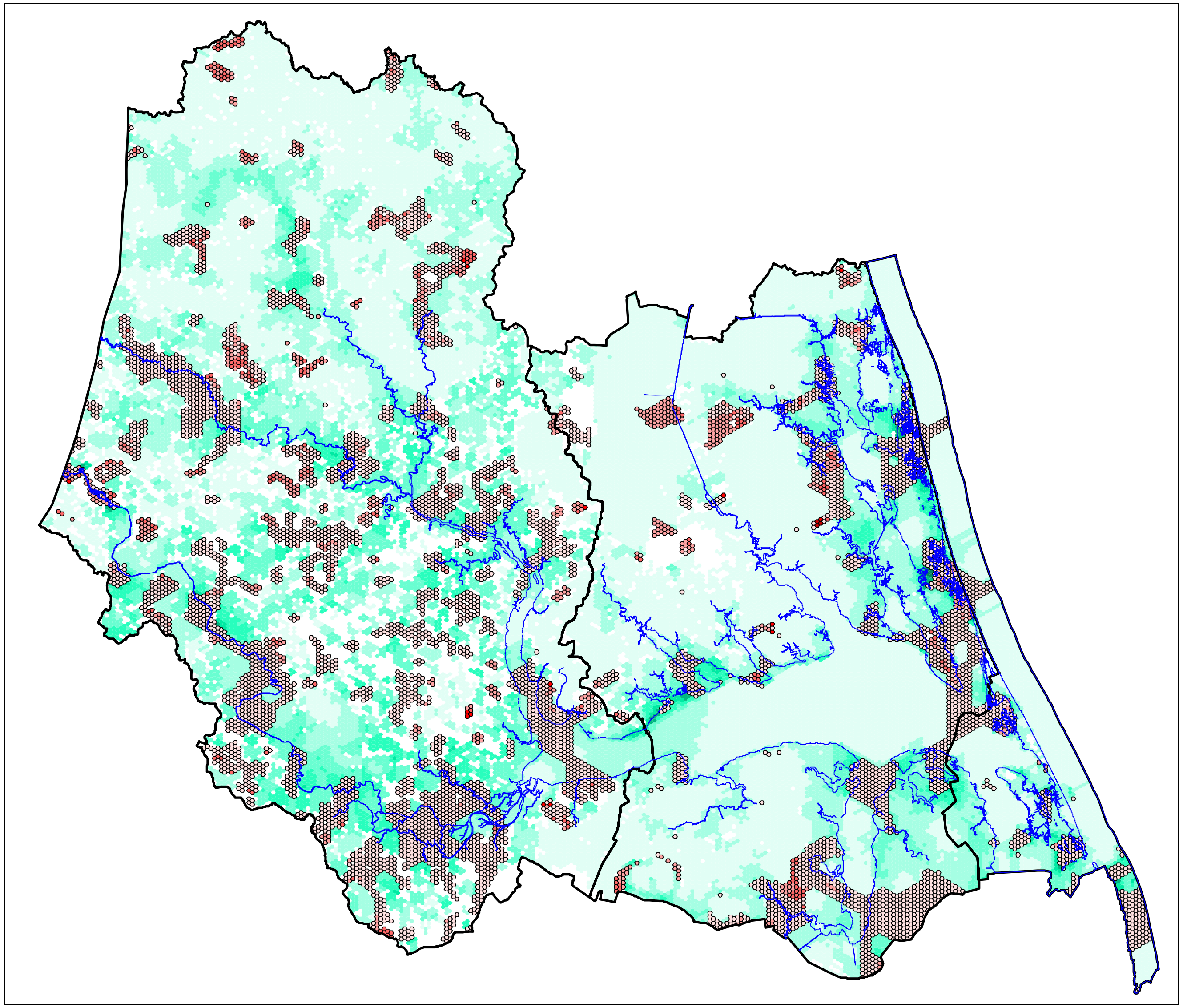
Map 6. MARXAN selections and selection frequencies using the full representation levels for natural resource targets.



Map 7. MARXAN selections and frequency of selection using the reduced representation levels for natural resource targets.



Map 8. MARXAN selections and selection frequencies using a stratified reduction of representation levels for natural resource targets. See Map 4 for legend.



CORROBORATING DATA AND DESIGNATIONS

To begin corroboration of the "computer-selected" SHAs, the committee assessed hexagon clusters on the map using local knowledge and decision support tables that included information on type and amount of natural resource targets, level of alteration, documented locations of fish abundance and existing ecological designations (i.e. Primary Nursery Areas, Significant Natural Heritage Areas) in order to refine the computer generated selections (Step 5 in SHA report). The designations and biological data used in this phase of the analysis are listed in Table 6. These data are meant to support computer-selected areas and identify important areas omitted by the MARXAN analysis. An omitted area could include a bay that was highly altered but where documentation exists on high occurrence of important fishery species. Ideally the regional expert panel would have local qualitative knowledge that further supported the area as having high fishery or habitat value. Areas with existing habitat designations that were not selected by MARXAN could also indicate areas that should be considered for manual addition to the list of proposed SHAs.

Table 6. Programs documenting fish abundance and designations indicating exceptional aquatic habitats in Region 1.

Data type	Description	Data source/availability
Ecological/functional designations	Anadromous Spawning Areas	MFC designation
	Blue crab spawning sanctuaries	MFC designation
	Oyster sanctuaries	MFC designation
	Estuarine fish nurseries (i.e., PNAs)	MFC designation
	Freshwater fish nurseries (i.e., inland PNAs)	DMF nomination/WRC designation
	Open shellfish harvesting waters	DEH-SS classification
	Significant Natural Heritage Areas (aquatic and terrestrial)	Natural Heritage Program designation
	Lands managed for conservation	One NC Naturally (DENR)
Species/ productivity data	Fish and benthic bioclassification (freshwater streams only)	DWQ program
	Juvenile anadromous and freshwater fish (i.e., river herring, shad, sturgeon, white perch)	DMF program 100, 135-juvenile sturgeon
	Juvenile estuarine fish (i.e., spot, croaker, flounder)	DMF program 120
	Shellfish densities (i.e., clams, oysters, bay scallops)	DMF program 635

ECOLOGICAL/FUNCTIONAL DESIGNATIONS

The waters and lands in Region 1 contain numerous ecologically based designations. The primary water-based designations (in order of prevalence) are Anadromous Fish Spawning Areas, aquatic Significant Natural Heritage Areas, freshwater fish nurseries (Inland PNAs), estuarine fish nurseries (i.e., PNAs), Crab Spawning Sanctuaries, and Oyster Sanctuaries. The primary land-based designations are terrestrial Significant Natural Heritage Areas and lands managed for conservation from the One-NC Naturally web server. Unlike other designations, lands managed for conservation is constantly expanding and the data presented is for 2001. The presence of ecological-based designations, especially Anadromous Fish Spawning Areas, was a factor in modifying the MARXAN selections.

SPECIES/PRODUCTIVITY DATA

Data on the distribution and abundance of juvenile fish in Albemarle Sound (i.e., DMF Program 100) were used in the *corroboration* phase of the Region 1 SHA designation process. These data were not used in the initial SHA identification process over concern that fish sampling data were "(1)…often nonrandom and the resulting fish distribution may not be representative, (2) the information does not distinguish when and where areas haven't been sampled, as opposed to zero catch, and (3) factors other than habitat condition can influence species distribution and abundance (such as depleted stocks with constricted distributions)" (SHA AC 2006). However, for areas where sampling stations are located, these data can provide direct support for computer-selections in that area, as well as, identify specific areas omitted by the MARXAN analysis that appear to support critical juvenile fish habitat.

The NC DMF has conducted long-term biological sampling in the Albemarle Sound region to create indices of juvenile finfish abundance (DMF Program 100). The use of the more recent data from this program (2004-2007 trawl sampling) allowed for sufficient temporal and spatial coverage of Albemarle Sound and its habitat types. Albemarle Sound provides critical habitat for many fish species including marine, estuarine, freshwater, and anadromous species. Both single- and multi-species indices of juvenile fish distribution and abundance were analyzed from this data set. Single-species indices included analyses of important anadromous and abundant resource species including alewife, blueback herring, striped bass, white perch, spot, and Atlantic croaker. Multi-species indices included species richness (i.e., number of species present) and species diversity (i.e., Shannon-Weiner diversity index).

GIS maps of these single- and multi-species indices were created and compared to computer-selected areas from the MARXAN analysis. Additionally, predictive relationships between habitat features (i.e., natural resource targets) and these single- and multi-species indices were developed. Relationships between fish metrics and habitat variables are often non-linear; therefore, generalized additive models (GAMs) were used to statistically test the effectiveness of the natural resource targets and alteration scores at identifying areas in Albemarle Sound of importance to juvenile fish.

A ranking system for all sampling stations was created based on the single- and multi-species indices to simplify map interpretations. Indices values were reduced to a scale of 0-5, where 0 indicates no individuals of a given species were captured at that given station from 2004-2007 and 5 indicates an extremely high number of individuals of a given species captured at that given station from 2004-2007. Rankings 1-4 are scaled as the following: (1) index value falls within the lower 25% of all sampling stations, (2) index value falls within the lower 26-50% of all sampling stations, (3) index value falls within the upper 51-75% of all sampling stations, and (4) index value falls within the upper 76-100% of all sampling stations. Mapping results indicated that MARXAN-selected areas encompassed many of the fish sampling stations where the abundances of the select species, as well as species richness and diversity were of the highest values. In some instances, the mapping results were useful in identifying areas of high juvenile fish habitat value that were omitted by the MARXAN analysis.

In general, stations with high species richness and diversity were distributed across Albemarle Sound. Juvenile alewife, blueback herring, striped bass, and white perch were highly abundant in the western part of the sound including the Chowan River where salinities are lower, and were nearly absent at many stations located in the eastern part of the sound. Spot were the most widely distributed species analyzed, with greater abundances at more saline stations. Atlantic croaker were absent at most stations in the western part of the sound including the Chowan River but highly abundant in the middle and eastern portions of the sound where salinities are higher.

GAM results identified temporal trends in distributions and abundances including annual and monthly variation, along with the effect of the abiotic factors temperature, dissolved oxygen, and salinity on species richness, species diversity, and the distributions and abundances of the anadromous and resource species listed above. Sediment type (i.e., mud vs. sand) was a significant predictor of species distribution, as were sampling depth and the amount of shallow water (< 6 ft. deep) present at a sampling location. The effects of the amount of wetland habitat and the amount of SAV present at a sampling location on fish distribution and abundance were determined but the results were inconclusive. Sampling does not occur in either of these habitats and it is believed that sampling adjacent to them, as is done in the DMF Program 100 survey, is insufficient in order to accurately determine the relationship between these habitats and fish abundance. Additionally, larger habitat areas (e.g., areas with highest amounts of SAV) are insufficiently sampled, thus restricting conclusions about the species-habitat relationships. Alteration score was a significant predictor of distribution for many of the species analyzed, whereby the probability of capture of an individual of a given species was significantly lower at stations with alteration scores generally greater than two. This latter finding supports the alteration scores that were used in the MARXAN analysis. A full report on this Region 1 SHA corroboration analysis can be found in Ellis et al. 2009.

OTHER CORROBORATING INFORMATION

Corroboration may not be limited to MARXAN selections, but also total alteration scores. For example, the presence of wetland restoration projects could suggest that a site is actually in better condition than the alteration score reflects. Conversely, expert knowledge of unacknowledged alterations could lead to the committee de-selecting a site since it is actually more altered than thought. The total alteration scores could also be modified by recent breakthroughs in handling other sources of information. For example, the DWQ use support ratings were useable once we acquired ancillary data on ratings for each use of a water body. However, the ratings were generally limited to the best use. So for 303(d) list waters, we still do not know the full extent of aquatic life impairment. But this information can be used as an indicator of alteration where total alteration scores suggest relatively low impairment. Corroborating information regarding the alterations of an area was used only in the expert modification phase; alteration scores were not modified to re-run MARXAN scenarios.

IDENTIFICATION OF STRATEGIC HABITAT AREAS

The SHA report committee grouped selected hexagons of similar alteration level into manageable polygons for the corroboration and identification process. The SHA report 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 report committee considered: 1) MARXAN final selections and frequency of selection, 1) the current habitat condition, 2) biological supporting data, and 3) connection with adjacent selections and protected area. However, supporting narrative documentation for these areas was vague and inadequate.

Process details are provided herein to verify SHAs in Region 1, beyond what was required in the original SHA process to assist with corroboration of such a large area. This includes providing summary tables on information about the computer-selected polygons. Also, as a first step in the corroboration, the group limited selections to a focused area that included all area within a 500 m buffer of open waters and streams. They also limited selections to areas within North Carolina (did not select any areas within Virginia). This focus area was needed to draw committee attention to areas within MFC or WRC jurisdiction. A 500-meter buffer was then applied to the area to capture adjoining wetland and stream selections. This particular distance was chosen because the hexagons were approximately 500 meters wide.

Decision support materials were presented such that criteria could be consistently applied over a large area. Therefore, a series of tables (Tables 7-9) and maps (see Data/Information Directory) were developed to represent information on MARXAN clusters within the focus area. The tables summarize information within the cluster, whereas the maps show spatially what is within and between the clusters.

MARXAN SELECTIONS IN FOCUS AREA

Basic Information

Table 7 provides basic qualitative information on conditions present within each cluster. Column explanations are provided below.

Habitats present – X where habitat is present in cluster

Ecological designations – X where designation is present in cluster

- IPNA – Inland Primary Nursery Areas
- AFSA – Anadromous Fish Spawning Areas
- LMFC – Lands Managed for Conservation
- SNHA – Significant Natural Heritage Areas (includes both aquatic and terrestrial areas)
- FNA – Coastal Fish Nursery Areas
- CSS – Crab Spawning Sanctuaries
- OS – Oyster Sanctuaries

MARXAN

- Selection frequency – For each hexagon, summed the selection frequencies for 3 scenarios run (max = 300) and then averaged across the entire cluster. For example, the cluster (#10) described in the following table is composed of three hexagons.

Cluster #	Hexagon #	Full scenario freq.	Reduced scenario freq.	Stratified scenario freq.	Total
10	14	40	24	16	80
10	17	36	7	11	54
10	18	72	57	33	162
Total		148	88	60	298
Average		49	29	20	**98**

- Alteration scores – Average alteration score, per hexagon, within cluster. Higher scores represent greater alteration.

Fish sampling data

- Fish data present – T = trawl data, S = seine data, T&S = trawl and seine data, and N = no data
- Trawl and seine data – Average abundance rank (0-5; none - high) for each cluster with fish data present. Note that it's only an average where there was >1 station within the cluster. Most of the numbers for a cluster represent one data point and data from 2004-2007

Table 7. Basic description of clusters selected by MARXAN. Note: MARXAN selection frequency is the average of the cumulative frequency of three scenarios run, per hexagon included with cluster. Abbreviations: IPNA = Inland Primary Nursery Areas, AFSA = Anadromous Fish Spawning Areas, LMFC = lands managed for conservation, SNHA = Significant Natural Heritage Areas (including both aquatic and terrestrial), FNA = (coastal) fish nursery areas, CSS = Crab Spawning Sanctuaries, OS = Oyster Sanctuaries, S = seine, T = trawl, and N = no sampling.

		Habitats Present									Ecological Designations present							MARXAN		Fish Abundance Data (average rank 0-5)												
																					Trawl Data						Seine Data					
Cluster	Acres	Creek/river	Interior wetland	Riparian upland	Riparian wetland	Soft bottom	Hard bottom	SAV	Streams	Shell bottom	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS	Selection frequency	Alteration score	Fish data present	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker
1	236	/	/	/	/	X	/	/	/	/	/	/	/	/	/	/	/	110	1.00	N	/	/	/	/	/	/	/	/	/	/	/	/
2	12,073	/	/	/	/	X	X	/	/	/	/	/	/	/	/	/	/	63	1.00	N	/	/	/	/	/	/	/	/	/	/	/	/
3	14,169	/	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	65	0.08	N	/	/	/	/	/	/	/	/	/	/	/	/
4	8,524	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	74	0.05	T	2	1	0	1	1	1	/	/	/	/	/	/
5	1,428	/	/	/	/	X	/	X	/	X	/	/	/	/	/	/	/	115	0.97	N	/	/	/	/	/	/	/	/	/	/	/	/
6	1,616	/	X	X	X	X	/	X	X	/	/	X	X	X	/	/	/	107	2.58	N	/	/	/	/	/	/	/	/	/	/	/	/
7	746	/	X	/	X	X	/	X	X	/	/	X	X	X	/	/	/	66	1.63	N	/	/	/	/	/	/	/	/	/	/	/	/
8	2,517	/	/	/	/	X	/	/	/	/	/	/	/	/	/	/	/	162	1.00	N	/	/	/	/	/	/	/	/	/	/	/	/
9	124	/	X	/	X	X	/	X	/	/	/	/	/	/	/	/	/	108	2.44	N	/	/	/	/	/	/	/	/	/	/	/	/
10	124	/	X	/	X	X	/	/	X	/	/	/	/	/	/	/	/	13	1.96	N	/	/	/	/	/	/	/	/	/	/	/	/
11	249	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	97	0.73	N	/	/	/	/	/	/	/	/	/	/	/	/
12	249	/	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	23	1.35	N	/	/	/	/	/	/	/	/	/	/	/	/
13	124	/	/	/	/	X	/	/	/	X	/	/	/	/	/	/	/	120	1.08	N	/	/	/	/	/	/	/	/	/	/	/	/
14	4,972	/	X	/	X	X	/	/	X	/	/	X	X	X	/	/	/	61	0.16	N	/	/	/	/	/	/	/	/	/	/	/	/
15	249	/	X	/	X	X	/	/	/	/	/	/	/	/	/	/	/	113	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
16	389	/	/	X	/	X	/	/	/	/	/	/	/	/	/	/	/	130	0.98	N	/	/	/	/	/	/	/	/	/	/	/	/
17	249	/	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	118	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
18	373	/	X	/	X	X	/	/	X	/	/	/	X	X	/	/	/	66	0.01	N	/	/	/	/	/	/	/	/	/	/	/	/
19	3,107	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	140	0.03	N	/	/	/	/	/	/	/	/	/	/	/	/
20	124	/	/	/	/	/	/	/	X	/	/	/	/	/	/	/	/	45	1.28	N	/	/	/	/	/	/	/	/	/	/	/	/

Cluster	Acres	Creek/river	Interior wetland	Riparian upland	Riparian wetland	Soft bottom	Hard bottom	SAV	Streams	Shell bottom	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS	Selection freq.	Alteration score	Fish data present	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker
21	6,215	/	X	X	X	X	/	X	X	X	/	/	X	X	/	X	/	194	0.42	N	/	/	/	/	/	/	/	/	/	/	/	/
22	2,486	/	X	/	X	X	/	X	/	X	/	/	/	/	/	/	/	142	1.08	N	/	/	/	/	/	/	/	/	/	/	/	/
23	249	X	X	X	X	/	/	/	X	/	/	/	/	/	/	/	/	63	0.55	N	/	/	/	/	/	/	/	/	/	/	/	/
24	561	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	127	1.05	N	/	/	/	/	/	/	/	/	/	/	/	/
25	249	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	128	0.03	N	/	/	/	/	/	/	/	/	/	/	/	/
26	22,124	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	110	0.11	N	/	/	/	/	/	/	/	/	/	/	/	/
27	2,237	/	X	X	X	X	/	/	X	/	/	/	X	X	/	/	/	127	0.27	N	/	/	/	/	/	/	/	/	/	/	/	/
28	124	/	/	/	/	X	X	/	/	/	/	/	/	/	/	/	/	83	1.01	N	/	/	/	/	/	/	/	/	/	/	/	/
29	124	/	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	130	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
30	249	/	X	/	/	/	/	/	/	/	/	/	X	X	/	/	/	150	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
31	2,734	/	X	X	X	X	/	X	X	X	/	/	X	X	X	/	/	106	0.57	N	/	/	/	/	/	/	/	/	/	/	/	/
32	124	/	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	78	0.15	N	/	/	/	/	/	/	/	/	/	/	/	/
33	621	/	/	/	/	X	/	/	/	X	/	/	/	/	/	/	/	44	1.01	N	/	/	/	/	/	/	/	/	/	/	/	/
34	9,073	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	127	0.11	N	/	/	/	/	/	/	/	/	/	/	/	/
35	2,113	/	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	147	0.19	N	/	/	/	/	/	/	/	/	/	/	/	/
36	249	/	X	X	X	X	/	X	/	X	/	/	/	/	/	/	/	79	1.77	N	/	/	/	/	/	/	/	/	/	/	/	/
37	12,305	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	115	0.21	N	/	/	/	/	/	/	/	/	/	/	/	/
38	2,362	/	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	116	0.39	N	/	/	/	/	/	/	/	/	/	/	/	/
39	124	/	/	X	/	X	/	X	/	X	/	/	/	/	/	/	/	116	2.41	N	/	/	/	/	/	/	/	/	/	/	/	/
40	870	X	X	X	X	X	/	/	/	/	/	X	X	X	/	/	/	124	0.36	N	/	/	/	/	/	/	/	/	/	/	/	/
41	17,898	X	X	X	X	X	/	X	X	/	X	X	X	X	/	/	/	116	0.05	T	4	3	0	2	1	4	/	/	/	/	/	/
42	2,610	X	X	/	X	X	/	/	X	/	/	X	X	X	/	/	/	84	0.11	N	/	/	/	/	/	/	/	/	/	/	/	/
43	124	/	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	63	0.12	N	/	/	/	/	/	/	/	/	/	/	/	/
44	5,096	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	110	0.37	N	/	/	/	/	/	/	/	/	/	/	/	/
45	124	/	/	/	/	X	/	X	/	/	/	/	/	/	/	/	/	182	0.11	N	/	/	/	/	/	/	/	/	/	/	/	/
46	746	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	101	1.19	N	/	/	/	/	/	/	/	/	/	/	/	/
47	2,362	X	X	X	X	/	/	X	X	/	/	/	/	/	/	/	/	120	0.53	N	/	/	/	/	/	/	/	/	/	/	/	/
48	1,119	/	X	X	X	X	/	X	X	/	/	X	X	X	/	/	/	210	0.15	N	/	/	/	/	/	/	/	/	/	/	/	/

Cluster	Acres	Creek/river	Interior wetland	Riparian upland	Riparian wetland	Soft bottom	Hard bottom	SAV	Streams	Shell bottom	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS	Selection freq.	Alteration score	Fish data present	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker
49	6,587	X	X	X	X	X	/	/	X	/	/	X	/	X	/	/	/	101	0.21	N	/	/	/	/	/	/	/	/	/	/	/	/
50	1,491	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	117	0.52	N	/	/	/	/	/	/	/	/	/	/	/	/
51	249	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	66	0.75	N	/	/	/	/	/	/	/	/	/	/	/	/
52	124	/	X	X	X	X	/	X	X	/	/	/	/	/	/	/	/	177	1.17	N	/	/	/	/	/	/	/	/	/	/	/	/
53	124	/	/	X	/	X	/	X	/	/	/	/	/	/	/	/	/	157	1.01	N	/	/	/	/	/	/	/	/	/	/	/	/
54	1,491	/	X	X	X	X	/	X	X	/	/	/	/	/	/	/	/	111	1.21	N	/	/	/	/	/	/	/	/	/	/	/	/
55	36,666	X	X	X	X	X	/	X	X	/	/	X	X	X	/	/	/	72	0.25	T&S	4	3	1	2	1	1	3.2	3.6	2.8	3	2.6	1
56	1,616	/	X	X	X	X	/	X	X	/	/	/	/	/	/	/	/	95	0.72	N	/	/	/	/	/	/	/	/	/	/	/	/
57	621	/	X	X	X	X	/	/	/	/	/	/	/	X	/	/	/	68	0.56	N	/	/	/	/	/	/	/	/	/	/	/	/
58	6,960	/	X	X	X	X	/	X	X	/	/	X	/	X	/	/	/	152	0.49	T&S	3	3	1	1	1	1	4	3	1	1	1	3
59	1,119	X	X	X	X	X	/	/	X	/	/	X	/	/	/	/	/	49	1.01	N	/	/	/	/	/	/	/	/	/	/	/	/
60	4,350	/	X	X	X	X	/	X	X	/	/	/	/	X	/	/	/	90	0.44	N	/	/	/	/	/	/	/	/	/	/	/	/
61	3,356	/	X	X	X	X	/	/	X	/	X	/	/	X	/	/	/	91	0.36	N	/	/	/	/	/	/	/	/	/	/	/	/
62	14,666	X	X	X	X	X	X	/	X	/	X	X	X	X	/	/	/	171	0.22	N	/	/	/	/	/	/	/	/	/	/	/	/
63	870	/	X	/	/	/	/	/	X	/	/	/	/	X	/	/	/	137	0.01	N	/	/	/	/	/	/	/	/	/	/	/	/
64	373	X	X	/	X	/	/	/	X	/	/	X	/	X	/	/	/	79	0.05	N	/	/	/	/	/	/	/	/	/	/	/	/
65	124	/	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	15	0.86	N	/	/	/	/	/	/	/	/	/	/	/	/
66	249	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	152	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
67	124	/	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	120	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
68	1,616	X	X	X	X	X	X	/	X	/	X	X	/	X	/	/	/	219	0.53	N	/	/	/	/	/	/	/	/	/	/	/	/
69	1,740	X	X	X	X	/	/	/	X	/	/	X	/	X	/	/	/	143	0.01	N	/	/	/	/	/	/	/	/	/	/	/	/
70	1,491	/	X	/	X	X	/	/	X	/	/	X	X	X	/	/	/	103	0.08	N	/	/	/	/	/	/	/	/	/	/	/	/
71	68,864	/	X	X	X	X	/	X	X	/	X	X	X	X	X	/	/	96	0.71	S	/	/	/	/	/	/	3	3	0	1	1	1
72	6,836	X	X	X	X	X	/	/	X	/	/	X	X	X	/	/	/	121	0.10	T	4	3	1	0	3	0	/	/	/	/	/	/
73	2,113	/	X	X	X	X	/	/	X	/	/	X	/	/	/	/	/	141	0.11	N	/	/	/	/	/	/	/	/	/	/	/	/
74	124	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	39	0.25	N	/	/	/	/	/	/	/	/	/	/	/	/
75	249	/	X	/	/	/	/	/	X	/	/	/	X	X	/	/	/	105	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
76	124	X	X	X	X	/	/	/	/	/	/	/	/	/	/	/	/	115	0.19	N	/	/	/	/	/	/	/	/	/	/	/	/

Cluster	Acres	Creek/river	Interior wetland	Riparian upland	Rip. wetland	Soft bottom	Hard bottom	SAV	Streams	Shell bottom	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS	Selection freq.	Alteration score	Fish data present	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker	Diversity	Richness	River Herring	Striped bass	White perch	Atlantic croaker
77	6,339	X	X	X	X	/	/	/	X	/	/	X	X	X	/	/	/	132	0.09	N	/	/	/	/	/	/	/	/	/	/	/	/
78	3,107	X	X	X	X	/	/	/	X	/	/	X	X	X	/	/	/	116	0.19	S	/	/	/	/	/	/	2	2	1	1	0	0
79	497	X	X	X	X	/	/	/	X	/	/	/	/	/	/	/	/	99	0.45	N	/	/	/	/	/	/	/	/	/	/	/	/
80	870	X	X	X	X	/	/	/	X	/	/	X	/	/	/	/	/	54	0.89	N	/	/	/	/	/	/	/	/	/	/	/	/
81	497	X	X	X	X	X	/	/	/	/	/	/	/	/	/	/	/	103	0.63	N	/	/	/	/	/	/	/	/	/	/	/	/
82	124	/	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	99	0.59	N	/	/	/	/	/	/	/	/	/	/	/	/
83	6,346	X	X	X	X	X	X	X	X	/	X	X	X	X	/	/	/	300	1.70	N	/	/	/	/	/	/	/	/	/	/	/	/
84	124	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	141	0.98	N	/	/	/	/	/	/	/	/	/	/	/	/
85	5,469	X	X	X	X	X	/	/	X	/	/	X	/	X	/	/	/	118	0.20	N	/	/	/	/	/	/	/	/	/	/	/	/
86	124	/	/	/	/	/	/	/	X	/	/	/	/	/	/	/	/	128	0.00	N	/	/	/	/	/	/	/	/	/	/	/	/
87	8,700	X	X	X	X	X	/	X	X	/	X	X	X	X	/	/	/	65	0.70	T	2	2	1	1	2	1	/	/	/	/	/	/
88	1,491	X	X	X	X	/	/	/	X	/	/	X	/	/	/	/	/	128	0.09	N	/	/	/	/	/	/	/	/	/	/	/	/
89	124	X	X	X	X	/	/	/	/	/	/	/	/	/	/	/	/	94	0.17	N	/	/	/	/	/	/	/	/	/	/	/	/
90	497	/	X	/	/	/	/	/	X	/	/	X	/	/	/	/	/	107	0.18	N	/	/	/	/	/	/	/	/	/	/	/	/
91	1,740	X	X	X	X	X	/	/	X	/	/	/	X	/	/	/	/	87	0.46	N	/	/	/	/	/	/	/	/	/	/	/	/
92	2,113	X	X	X	X	X	/	/	X	/	/	/	X	X	/	/	/	33	1.87	N	/	/	/	/	/	/	/	/	/	/	/	/
93	2,610	X	X	X	X	X	/	/	X	/	/	X	/	/	/	/	/	101	0.22	N	/	/	/	/	/	/	/	/	/	/	/	/
94	29,773	/	X	X	X	X	/	X	X	/	/	/	X	X	/	/	/	131	0.48	T	4	3	0	1	1	4	/	/	/	/	/	/
95	7,333	X	X	X	X	X	/	/	X	/	/	/	X	/	/	/	/	105	0.17	N	/	/	/	/	/	/	/	/	/	/	/	/
96	13,175	X	X	X	X	X	X	/	X	/	/	X	/	/	/	/	/	140	0.19	N	/	/	/	/	/	/	/	/	/	/	/	/
97	124	X	X	/	X	/	/	/	X	/	/	/	/	/	/	/	/	90	0.63	N	/	/	/	/	/	/	/	/	/	/	/	/
98	994	X	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	89	0.41	N	/	/	/	/	/	/	/	/	/	/	/	/
99	2,734	X	X	X	X	X	/	X	X	/	/	/	X	/	/	/	/	93	0.32	N	/	/	/	/	/	/	/	/	/	/	/	/
100	3,356	X	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	124	0.22	N	/	/	/	/	/	/	/	/	/	/	/	/
101	621	X	X	X	X	X	/	/	X	/	/	/	/	/	/	/	/	109	1.00	N	/	/	/	/	/	/	/	/	/	/	/	/
102	870	/	X	/	/	/	/	/	X	/	/	/	/	/	/	/	/	98	0.52	N	/	/	/	/	/	/	/	/	/	/	/	/
103	196	/	X	X	/	X	/	/	X	/	/	/	X	/	/	/	/	115	0.38	N	/	/	/	/	/	/	/	/	/	/	/	/
104	1,740	X	X	X	X	X	/	/	X	/	/	/	X	/	/	/	/	148	0.13	N	/	/	/	/	/	/	/	/	/	/	/	/
105	124	/	X	/	X	X	/	/	/	/	/	/	/	/	/	/	/	110	0.06	N	/	/	/	/	/	/	/	/	/	/	/	/

Quantitative Information

Table 8 provides quantitative information on the habitats and ecological designations captured by the MARXAN clusters. The columns are explained below.

Hexagons – this is the number of hexagons comprising a cluster. The number can be multiplied with the hexagon average quantities below to get total acres of X within each cluster.

Habitats present – average area (acres) of habitat, per hexagon, within clusters. Figure 2 shows the frequency distribution of habitat areas.

- Creek/river
- Interior wetland
- Riparian upland
- Riparian wetland
- Soft bottom
- SAV
- Streams
- Shell bottom

Ecological designations – average area (acres) of designation, per hexagon, within clusters. Figure 3 shows the frequency distribution of designation areas.

- IPNA – Inland Primary Nursery Areas
- AFSA – Anadromous Fish Spawning Areas
- LMFC – Lands Managed for Conservation
- SNHA – Significant Natural Heritage Areas (includes both aquatic and terrestrial areas)
- FNA – Coastal Fish Nursery Areas
- CSS – Crab Spawning Sanctuaries
- OS – Oyster Sanctuaries

Table 8. Some quantitative information for clusters selected by MARXAN. Abbreviations: IPNA = Inland Primary Nursery Areas, AFSA = Anadromous Fish Spawning Areas, LMFC = lands managed for conservation, SNHA = Significant Natural Heritage Areas (including both aquatic and terrestrial), FNA = (coastal) fish nursery areas, CSS = Crab Spawning Sanctuaries, and OS = Oyster Sanctuaries.

			Habitats Present (% of cluster area)								Ecological Designations (% of cluster area)						
Cluster	Acres	Hexagons	Creek/river	Interior wetland	Riparian upland	Riparian wetland	SAV	Shell bottom	Soft bottom	Streams	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS
1	236	2	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	12,073	97	0.0	0.0	0.0	0.0	0.0	0.0	99.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	14,169	114	0.0	54.5	0.0	1.0	0.0	0.0	44.4	0.1	0.0	44.2	44.6	59.7	0.0	0.0	0.0
4	8,524	69	5.8	87.9	0.0	2.6	0.0	0.0	3.0	0.2	0.0	8.0	69.8	96.7	0.0	0.0	0.0
5	1,428	12	0.0	0.0	0.0	0.0	7.7	1.3	90.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1,616	13	0.0	4.3	0.3	0.5	27.3	0.0	23.7	0.5	0.0	51.5	21.4	51.7	0.0	0.0	0.0
7	746	6	0.0	18.3	0.0	1.8	14.5	0.0	18.0	0.5	0.0	33.5	26.5	51.6	0.0	0.0	0.0
8	2,517	20	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	124	1	0.0	4.5	0.0	1.6	61.3	0.0	32.6	0.0	0.0	100.0	0.0	100.0	0.0	0.0	0.0
10	124	1	0.0	21.4	0.0	2.3	0.0	0.0	31.3	0.3	0.0	32.5	0.0	50.0	0.0	0.0	0.0
11	249	2	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	249	2	0.0	18.7	0.6	0.9	0.0	0.0	7.8	0.8	0.0	5.9	22.8	16.2	0.0	0.0	0.0
13	124	1	0.0	0.0	0.0	0.0	0.0	7.2	92.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	4,972	40	0.0	68.5	0.0	1.0	0.0	0.0	25.7	0.3	0.0	25.5	66.5	40.5	0.0	0.0	0.0
15	249	2	0.0	99.7	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	99.9	0.0	0.0	0.0	0.0
16	389	3	0.0	0.0	0.5	0.0	0.0	0.0	99.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	249	2	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
18	373	3	0.0	60.8	0.0	1.4	0.0	0.0	37.5	0.3	0.0	0.0	64.2	74.8	0.0	0.0	0.0
19	3,107	25	0.2	29.9	0.1	0.3	0.0	0.0	0.1	0.3	0.0	0.7	0.2	7.1	0.0	0.0	0.0
20	124	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	2.0	0.0	0.0	0.0	0.0
21	6,215	50	0.0	9.2	0.5	2.0	31.8	0.3	52.5	0.1	0.0	0.0	13.6	3.5	0.0	16.9	0.0

Cluster	Acres	Hexagons	Creek/river	Interior wetland	Riparian upland	Riparian wetland	SAV	Shell bottom	Soft bottom	Streams	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS
22	2,486	20	0.0	0.3	0.0	0.1	0.0	7.5	92.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	249	2	1.7	9.6	0.3	2.6	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	561	5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	249	2	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	22,124	178	3.6	76.1	0.1	1.8	0.0	0.0	0.0	0.1	0.0	3.3	63.3	39.2	0.0	0.0	0.0
27	2,237	18	0.0	25.7	0.1	0.0	0.0	0.0	0.1	0.5	0.0	0.0	14.3	16.4	0.0	0.0	0.0
28	124	1	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	124	1	0.0	27.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	249	2	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	0.0	0.0	0.0
31	2,734	22	0.0	24.4	0.7	2.9	0.0	1.8	67.7	0.0	0.0	0.0	21.5	27.0	1.5	0.0	0.0
32	124	1	0.0	60.2	0.3	0.2	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	621	5	0.0	0.0	0.0	0.0	0.0	0.5	99.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	9,073	73	1.6	45.9	0.3	0.8	0.0	0.0	0.1	0.3	0.0	1.5	38.1	45.2	0.0	0.0	0.0
35	2,113	17	0.0	19.0	0.1	0.1	0.0	0.0	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	249	2	0.0	2.5	5.7	0.1	3.8	0.4	27.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	12,305	99	6.6	48.0	0.4	2.2	0.0	0.0	1.7	0.1	0.0	5.9	24.3	31.1	0.0	0.0	0.0
38	2,362	19	0.0	18.3	0.0	0.1	0.0	0.0	0.1	0.7	0.0	0.0	0.1	0.0	0.0	0.0	0.0
39	124	1	0.0	0.0	1.5	0.0	10.2	4.3	81.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	870	7	2.4	40.4	0.1	1.6	0.0	0.0	0.0	0.0	0.0	2.0	8.0	1.1	0.0	0.0	0.0
41	17,898	144	0.2	26.8	0.0	0.9	5.3	0.0	66.4	0.1	3.9	70.3	17.9	27.9	0.0	0.0	0.0
42	2,610	21	0.4	72.4	0.0	1.6	0.0	0.0	20.2	0.2	0.0	14.9	73.2	74.6	0.0	0.0	0.0
43	124	1	0.0	23.8	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	5,096	41	2.8	39.9	0.6	0.3	0.0	0.0	0.0	0.3	0.0	2.7	14.3	6.6	0.0	0.0	0.0
45	124	1	0.0	0.0	0.0	0.0	19.8	0.0	80.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	746	6	0.0	35.3	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	2,362	19	0.0	27.7	0.0	0.1	0.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	1,119	9	0.0	17.3	0.0	1.6	31.5	0.0	41.5	0.1	0.0	11.9	7.1	20.2	0.0	0.0	0.0
49	6,587	53	4.2	57.4	0.5	1.0	0.0	0.0	0.0	0.3	0.0	3.9	0.0	40.2	0.0	0.0	0.0
50	1,491	12	0.0	25.1	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Cluster	Acres	Hexagons	Creek/river	Interior wetland	Riparian upland	Riparian wetland	SAV	Shell bottom	Soft bottom	Streams	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS
51	249	2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	124	1	0.0	0.9	1.8	0.2	76.7	0.0	8.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	124	1	0.0	0.0	1.2	0.0	58.9	0.0	36.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	1,491	12	0.0	6.1	0.7	0.5	12.3	0.0	35.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	36,666	296	28.5	13.5	0.2	0.6	0.0	0.0	39.3	0.1	0.0	21.1	2.2	30.8	0.0	0.0	0.0
56	1,616	13	0.0	7.4	0.4	0.6	8.1	0.0	65.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	621	5	0.0	84.4	0.2	0.5	0.0	0.0	0.4	0.0	0.0	0.0	0.0	80.7	0.0	0.0	0.0
58	6,960	56	0.0	11.7	0.6	0.8	11.3	0.0	35.5	0.3	0.0	0.0	0.0	9.0	0.0	0.0	0.0
59	1,119	9	6.5	13.4	0.6	1.5	0.0	0.0	0.1	1.3	0.0	5.9	0.0	0.0	0.0	0.0	0.0
60	4,350	35	0.0	17.2	0.2	0.7	4.2	0.0	58.3	0.3	0.0	0.0	0.0	5.3	0.0	0.0	0.0
61	3,356	27	0.0	73.3	0.8	2.3	0.0	0.0	21.7	0.4	9.0	0.0	0.0	38.9	0.0	0.0	0.0
62	14,666	118	5.2	50.4	0.7	1.1	0.0	0.0	0.1	0.4	1.6	4.9	12.6	32.1	0.0	0.0	0.0
63	870	7	0.0	19.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	21.3	0.0	0.0	0.0
64	373	3	1.2	55.5	0.0	1.1	0.0	0.0	0.0	0.4	0.0	1.1	0.0	90.7	0.0	0.0	0.0
65	124	1	0.0	40.5	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
66	249	2	0.0	42.8	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
67	124	1	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
68	1,616	13	4.8	8.6	1.5	0.3	0.0	0.0	0.0	0.3	5.2	4.9	0.0	2.5	0.0	0.0	0.0
69	1,740	14	0.8	43.3	0.0	1.3	0.0	0.0	0.0	0.2	0.0	0.8	0.0	32.7	0.0	0.0	0.0
70	1,491	12	0.0	80.7	0.0	1.5	0.0	0.0	11.7	0.2	0.0	11.6	69.0	3.5	0.0	0.0	0.0
71	68,864	555	0.0	12.0	0.4	1.8	10.5	0.0	67.0	0.1	3.7	3.6	4.8	18.9	2.3	0.0	0.0
72	6,836	55	10.1	37.7	0.0	1.0	0.0	0.0	0.0	0.3	0.0	10.0	4.6	31.7	0.0	0.0	0.0
73	2,113	17	0.0	28.4	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
74	124	1	0.0	16.3	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	249	2	0.0	99.7	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	68.6	52.4	0.0	0.0	0.0
76	124	1	3.3	16.5	0.9	4.3	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0
77	6,339	51	11.1	60.8	0.2	1.2	0.0	0.0	0.0	0.2	0.0	10.8	33.3	47.1	0.0	0.0	0.0
78	3,107	25	11.4	54.7	0.5	0.8	0.0	0.0	0.0	0.1	0.0	11.2	23.1	66.3	0.0	0.0	0.0

Cluster	Acres	Hexagons	Creek/river	Interior wetland	Riparian upland	Riparian wetland	SAV	Shell bottom	Soft bottom	Streams	IPNA	AFSA	LMFC	SNHA	FNA	CSS	OS
79	497	4	2.3	12.5	0.4	2.3	0.0	0.0	0.0	0.4	0.0	2.3	0.0	0.0	0.0	0.0	0.0
80	870	7	3.2	54.6	0.7	2.4	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0
81	497	4	0.3	23.1	0.0	0.8	0.0	0.0	0.2	0.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0
82	124	1	0.0	2.3	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
83	6,346	51	14.2	8.2	2.7	2.1	0.1	0.0	0.8	0.4	8.8	9.9	0.1	7.6	0.0	0.0	0.0
84	124	1	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
85	5,469	44	3.3	44.0	0.2	2.6	0.0	0.0	0.1	0.3	0.0	2.6	0.0	16.8	0.0	0.0	0.0
86	124	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
87	8,700	70	3.7	29.9	0.7	1.9	0.4	0.0	7.4	0.7	7.3	9.8	10.0	22.5	0.0	0.0	0.0
88	1,491	12	3.5	61.9	0.3	2.6	0.0	0.0	0.0	0.4	0.0	2.7	0.0	3.6	0.0	0.0	0.0
89	124	1	5.8	22.1	2.4	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	497	4	0.0	15.8	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.7	0.0	0.0	0.0	0.0	0.0
91	1,740	14	10.7	54.2	0.3	4.0	0.0	0.0	0.7	1.0	0.0	0.0	38.4	0.0	0.0	0.0	0.0
92	2,113	17	1.8	63.6	0.8	0.9	0.0	0.0	0.0	0.6	0.0	0.0	61.1	8.9	0.0	0.0	0.0
93	2,610	21	3.1	31.8	0.5	1.3	0.0	0.0	0.0	0.5	0.0	2.9	0.0	0.0	0.0	0.0	0.0
94	29,773	240	0.0	20.3	0.5	3.0	11.4	0.0	54.6	0.1	0.0	0.0	16.2	13.2	0.0	0.0	0.0
95	7,333	59	12.3	62.2	0.3	6.0	0.0	0.0	5.0	0.5	0.0	0.0	22.0	0.0	0.0	0.0	0.0
96	13,175	106	2.9	55.9	0.8	1.8	0.0	0.0	0.2	0.3	0.0	0.6	0.0	0.0	0.0	0.0	0.0
97	124	1	30.5	60.7	0.0	8.7	0.0	0.0	0.0	0.1	0.0	0.0	28.1	0.0	0.0	0.0	0.0
98	994	8	8.0	64.2	0.3	4.1	0.0	0.0	0.3	0.6	0.0	0.0	1.1	0.0	0.0	0.0	0.0
99	2,734	22	1.7	42.2	0.4	2.3	0.1	0.0	17.5	1.3	0.0	0.0	25.9	0.0	0.0	0.0	0.0
100	3,356	27	3.0	26.7	0.5	2.5	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
101	621	5	1.8	25.2	0.3	1.3	0.0	0.0	0.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
102	870	7	0.0	10.1	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
103	196	2	0.0	58.6	1.1	0.0	0.0	0.0	4.2	1.6	0.0	0.0	96.2	0.0	0.0	0.0	0.0
104	1,740	14	2.5	44.2	0.6	1.5	0.0	0.0	0.2	0.8	0.0	0.0	19.9	0.0	0.0	0.0	0.0
105	124	1	0.0	64.7	0.0	1.5	0.0	0.0	2.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avg	**3,934**	**32**	**2.2**	**31.2**	**0.4**	**1.1**	**3.9**	**0.2**	**19.2**	**0.4**	**0.4**	**5.2**	**13.8**	**15.4**	**0.0**	**0.2**	**0.0**
Max	**68,864**	**555**	**30.5**	**100.0**	**5.7**	**8.7**	**76.7**	**7.5**	**100.0**	**1.6**	**9.0**	**100.0**	**100.0**	**100.0**	**2.3**	**16.9**	**0.0**

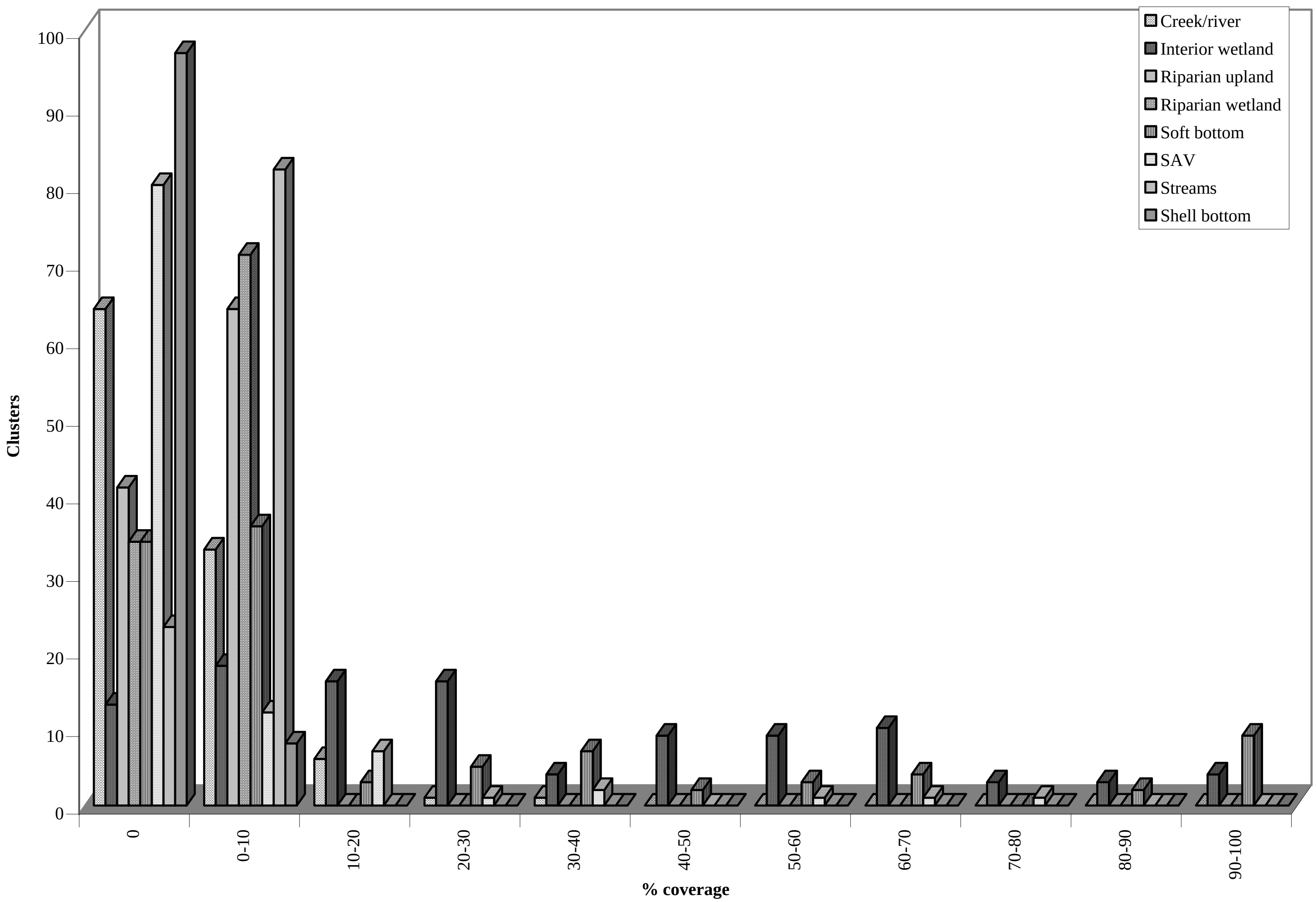


Figure 2. Frequency distribution of average habitat areas among MARXAN clusters.

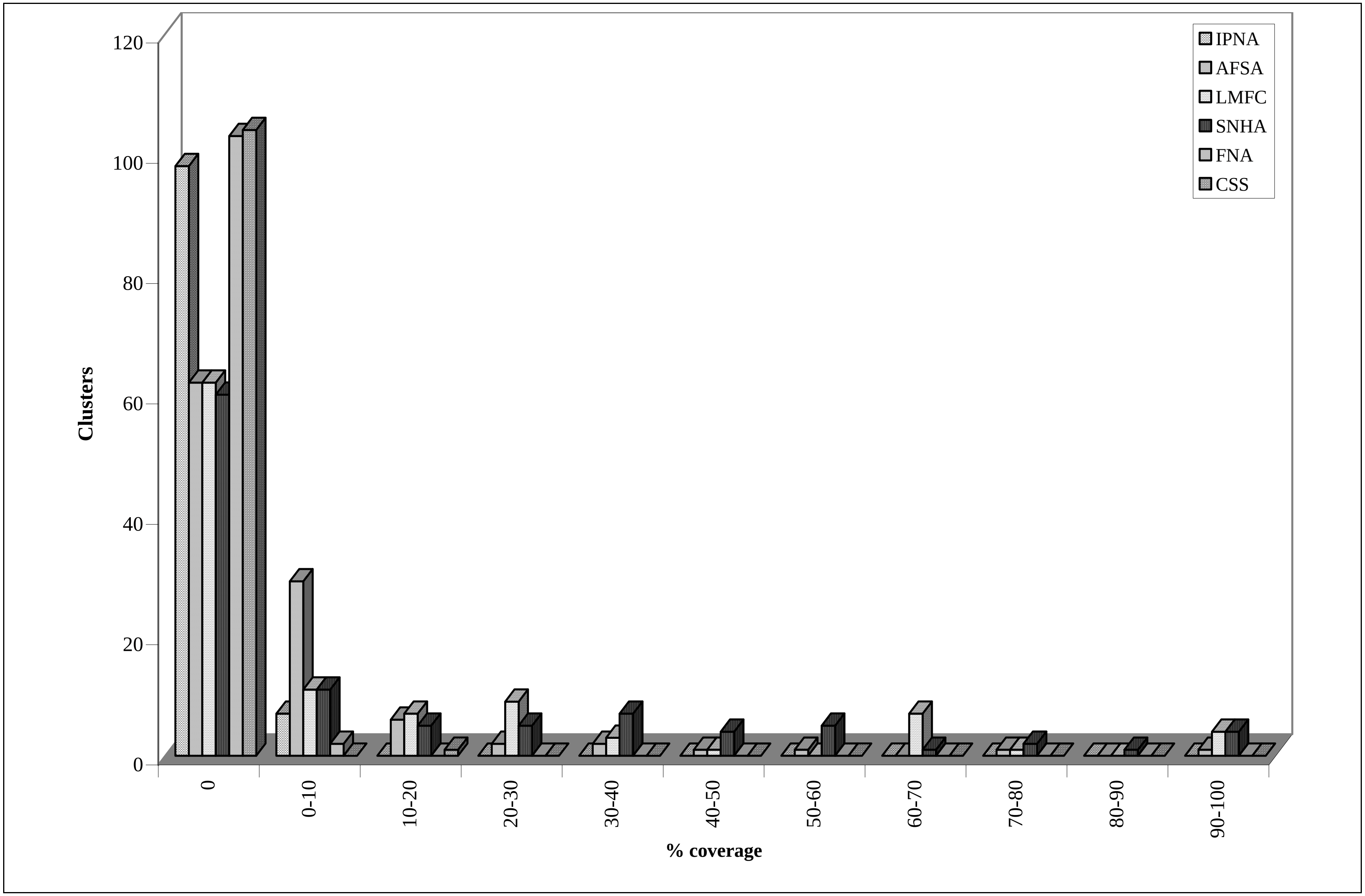


Figure 3. Frequency distribution of average designation area among MARXAN clusters.

Ranking Information

Table 9 provides the results of an overall ranking of ecological designations, selection frequency, and alteration score. The columns are explained below.

Ecological designations rank – scaled (0-1) quantities for each designation added together and ranked to score of 0-100; 100 being the widest coverage and density of designations. The 0-1 scaling was calculated using the range of average area for each designation. For example, the maximum average area of AFSAs (107.17 acres) was used as the denominator to yield the 0-1 AFSA values for each cluster. So even though a designation never occupies the largest portion of a hexagon, it may still contribute to the total rank based on a common 0-1 scale among designations. Figure 4 shows the frequency distribution of ecological designation ranks.

Selection frequency rank – scaled to score of 0-100; 100 being most selected cluster among the three scenarios run. Figure 4 shows the frequency distribution of selection frequency ranks.

Alteration score rank – scaled to score of 0-100; 100 being the most altered. Figure 4 shows the frequency distribution of alteration score ranks.

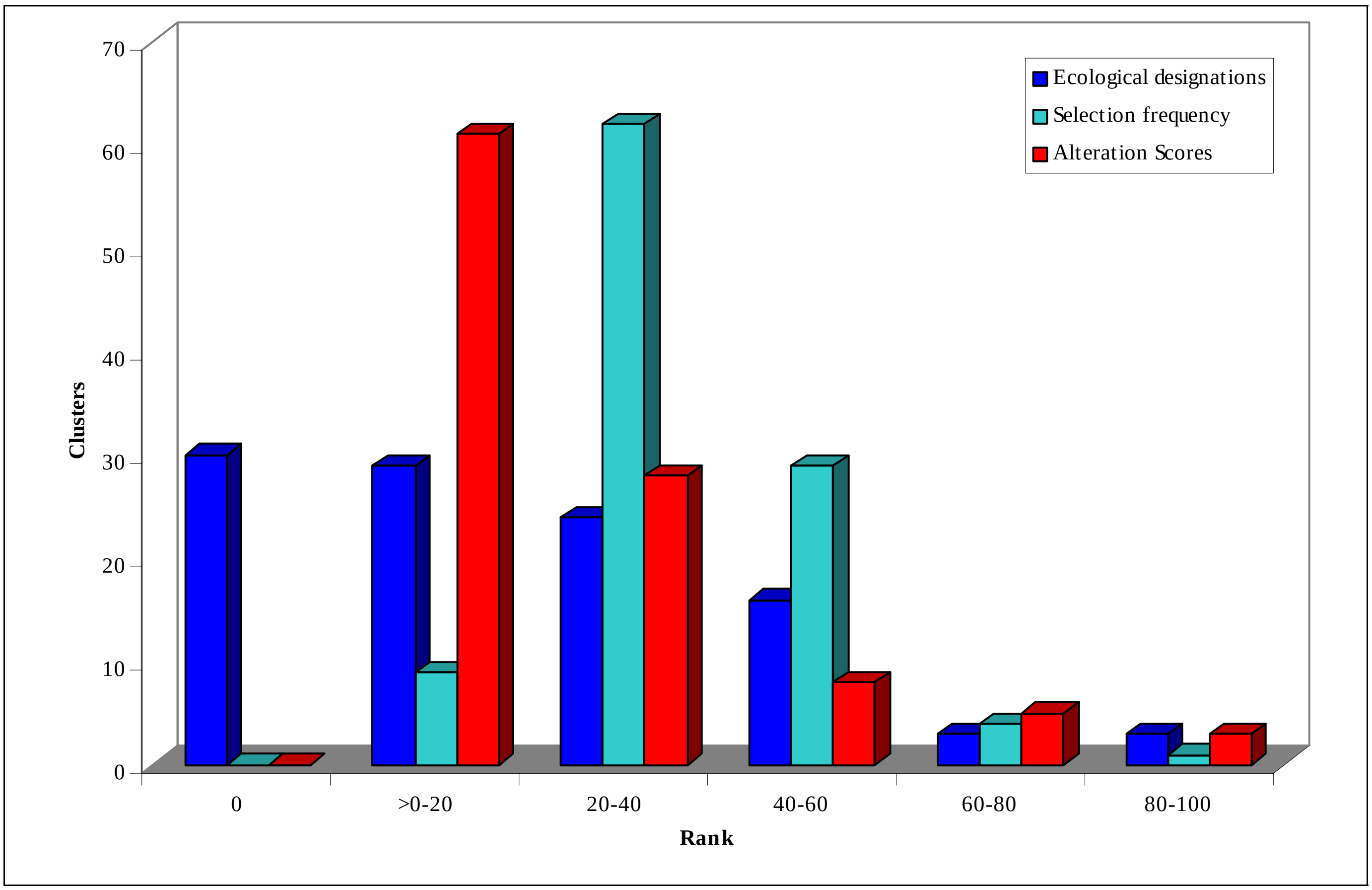


Figure 4. Frequency distribution of ecological designations, selection frequencies, and total alteration score among clusters

Table 9. Some information on MARXAN clusters ranked from the quantitative information. For ecological designation ranks, quantities for each designation were added together and scaled to a score of 0-100; 100 being the widest coverage and density of designations. For selection frequency rank, higher numbers indicate greater frequency of selection. And high alteration ranks indicate greater alteration.

Cluster	Acres	Ecological Designation Rank (0-100)	Selection Frequency Rank (0-100)	Alteration Score Rank (0-100)
1	236	0	37	39
2	12,073	0	21	39
3	14,169	47	22	3
4	8,524	64	25	2
5	1,428	0	38	38
6	1,616	71	36	100
7	746	100	22	63
8	2,517	0	54	39
9	124	55	36	95
10	124	82	4	76
11	249	14	32	28
12	249	95	8	52
13	124	0	40	42
14	4,972	50	20	6
15	249	41	38	0
16	389	0	43	38
17	249	27	39	0
18	373	55	22	0
19	3,107	19	47	1
20	124	27	15	50
21	6,215	41	65	16
22	2,486	0	47	42
23	249	0	21	21
24	561	22	42	41
25	249	0	43	1
26	22,124	59	37	4
27	2,237	38	42	10
28	124	0	28	39
29	124	0	43	0
30	249	55	50	0
31	2,734	37	35	22
32	124	0	26	6
33	621	0	15	39
34	9,073	55	42	4
35	2,113	19	49	7

Cluster	Acres	Ecological Designation Rank (0-100)	Selection Frequency Rank (0-100)	Alteration Score Rank (0-100)
36	249	0	26	69
37	12,305	40	38	8
38	2,362	17	39	15
39	124	0	39	93
40	870	31	41	14
41	17,898	26	39	2
42	2,610	68	28	4
43	124	0	21	4
44	5,096	29	37	14
45	124	0	61	4
46	746	18	34	46
47	2,362	14	40	20
48	1,119	36	70	6
49	6,587	36	34	8
50	1,491	14	39	20
51	249	0	22	29
52	124	0	59	45
53	124	0	52	39
54	1,491	0	37	47
55	36,666	20	24	10
56	1,616	0	32	28
57	621	27	23	22
58	6,960	5	51	19
59	1,119	18	16	39
60	4,350	3	30	17
61	3,356	14	30	14
62	14,666	43	57	8
63	870	23	46	0
64	373	36	26	2
65	124	27	5	33
66	249	0	51	0
67	124	0	40	0
68	1,616	17	73	21
69	1,740	35	48	0
70	1,491	43	34	3
71	68,864	13	32	28
72	6,836	36	40	4
73	2,113	16	47	4
74	124	0	13	10
75	249	55	35	0
76	124	27	38	7

Cluster	Acres	Ecological Designation Rank (0-100)	Selection Frequency Rank (0-100)	Alteration Score Rank (0-100)
77	6,339	55	44	3
78	3,107	56	39	7
79	497	14	33	18
80	870	19	18	34
81	497	7	34	24
82	124	0	33	23
83	6,346	34	100	66
84	124	0	47	38
85	5,469	48	39	8
86	124	0	43	0
87	8,700	29	22	27
88	1,491	16	43	3
89	124	0	31	7
90	497	14	36	7
91	1,740	16	29	18
92	2,113	27	11	72
93	2,610	14	34	8
94	29,773	16	44	19
95	7,333	12	35	6
96	13,175	13	47	7
97	124	27	30	24
98	994	7	30	16
99	2,734	24	31	12
100	3,356	9	41	8
101	621	16	36	39
102	870	19	33	20
103	196	27	38	15
104	1,740	29	49	5
105	124	0	37	2

EXPERT MODIFICATIONS TO MARXAN

The committee used the data presented in tables 7-9 and the supporting appendix maps to cut, extend, and/or consolidate MARXAN selections within the focus area. The consolidations were based on avoiding what the group considered over-represented habitats (i.e., soft bottom >6 ft) and connecting similar contiguous areas or under-represented habitats. Some natural resource targets were also clipped out of MARXAN clusters. For example, deep soft bottom areas were removed in some areas adjacent to Anadromous Fish Spawning Areas (AFSAs) and coastal ocean waters lacking hard bottom resources. The primary reason for excluding much of the riverine or estuarine soft bottom (>6 ft) was to prevent over-representation of this resilient habitat. However, riverine soft bottom (>6 ft) was included in historically important areas for anadromous fish. In deeper areas along coastal ocean waters soft bottom >6 ft was excluded because of its lower functional importance relative to nearshore areas (Sara Winslow/DMF, pers. com. 2008). The reasons for including or excluding deeper soft bottom areas depended on the relative functional importance of adjoining shallow and deep areas.

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. Similarly, irregular shaped MARXAN selections (such as a rectangular area jutting out from a circular cluster) were examined and if no sound ecological reason was known for including that unusual boundary, it was deleted. The committee and support staff also decided that certain ecological designations indicate exceptional habitat for designation. Those designations included some Anadromous Fish Spawning Areas for their importance to blueback herring and alewife, over-fished species in this particular region. For continuity, we also expanded clusters into some unselected fish nursery areas (i.e., PNAs), oyster sanctuaries, and artificial reefs. Selections that were very small and isolated or in Virginia were not nominated at this stage.

The visual assessment was conducted systematically around the region, starting in Currituck Sound. From Currituck Sound, the assessment proceeded to Roanoke Island and points south to Oregon Inlet. Then the group decided to head west to the Chowan and Roanoke River, where the entirety of both rivers in North Carolina was nominated. The nomination also included the shallow shoreline of western Albemarle Sound up to the Highway 45 bridge. These particular river systems were classified AFSAs and deemed of particular importance to anadromous species based on biological data and expert opinion (Sara Winslow/DMF, pers. com., June 2008). They also contained a number of MARXAN clusters that were separated by unselected but extremely similar habitats. The site selection program did not select intervening areas because representation levels were already met. It was also considered inappropriate to select only fragments of a critical migratory spawning route. From there, the assessment proceeded east along the northern shore of Albemarle Sound then along the corresponding south shore. There were fewer nominations along the central part of Albemarle Sound even though many adjoining tributaries were classified AFSA because they occurred in more altered hydrologic units and the target amounts had been met by the less altered areas in the Chowan and Roanoke. However, the selections do cover some river mouth areas in the central sub-region (an important area for both anadromous and resident brackish water species).

In the process of reviewing and modifying clusters, the group noted some deviations between the reported alteration score and actual condition of a site based on local knowledge they had. These adjustments included lowering the alteration of NPDES-affected areas in the mouth of Roanoke River and middle Chowan River. There was also an entire creek system in Yeopim River that appeared unaltered by MARXAN, but had been filled, ditched and drained (Sara Winslow/DMF, pers. com., June 2008). Some nominations also contained DWQ impaired waters where total alteration scores were relatively low. The SHA nominations with DWQ impaired waters can be targeted for water quality restoration. On the other hand, Wayne Howell noted areas where altered wetlands had been restored. Since these restoration projects were well upstream of the focus area, it did not affect SHA nominations.

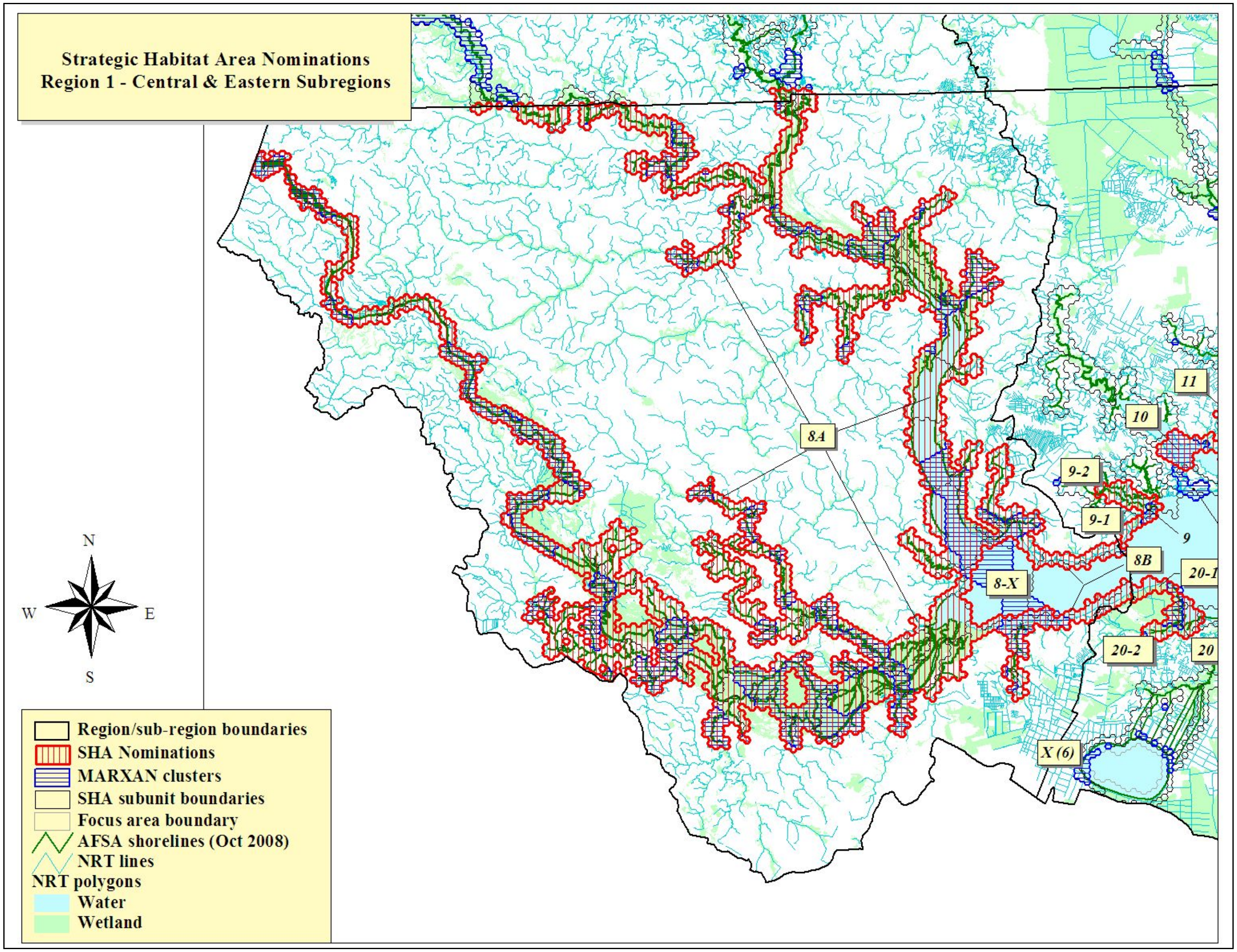
To help assess nominations, we divided the focus area into subunits based on 14-digit hydrologic units (Map 6). We then conducted a Bray-Curtiss similarity analysis using the NRT composition of the subunits. Specifically, we used Primer6 to perform a Hierarchical Cluster analysis on the average acreage of each NRT (fourth root transformed). The subunit groupings were differentiated at 75% similarity. A map depicting the alteration scores and similar subunits was provided, along with the location of degraded waters and fish sampling data. The map was used to expand MARXAN clusters into similar habitat areas, in terms of both natural resource targets and alterations. The modifications are documented in Table 10 and referenced on Maps 6a-b.

After the regional panel completed the modifications, there were 20 discrete areas selected for nomination, totaling 490,315 acres and 3,052 miles of habitat. Wetland targets comprised the largest amount of the nominations (258,181 acres and 1,769 miles of wetland edge), followed in decreasing order by soft bottom (211,812 acres and 449 miles of riparian uplands), water column (3,052 stream miles), SAV (18,743 acres), hard bottom (1,107 acres in riverine system and 9 miles in marine system), and shell bottom (457 acres) (Table 11, Map 6). The SHA nominations form a network of priority areas for protection and enhancement ranging from the upstream watersheds of the Albemarle, through the sounds, out Oregon Inlet and into the coastal ocean.

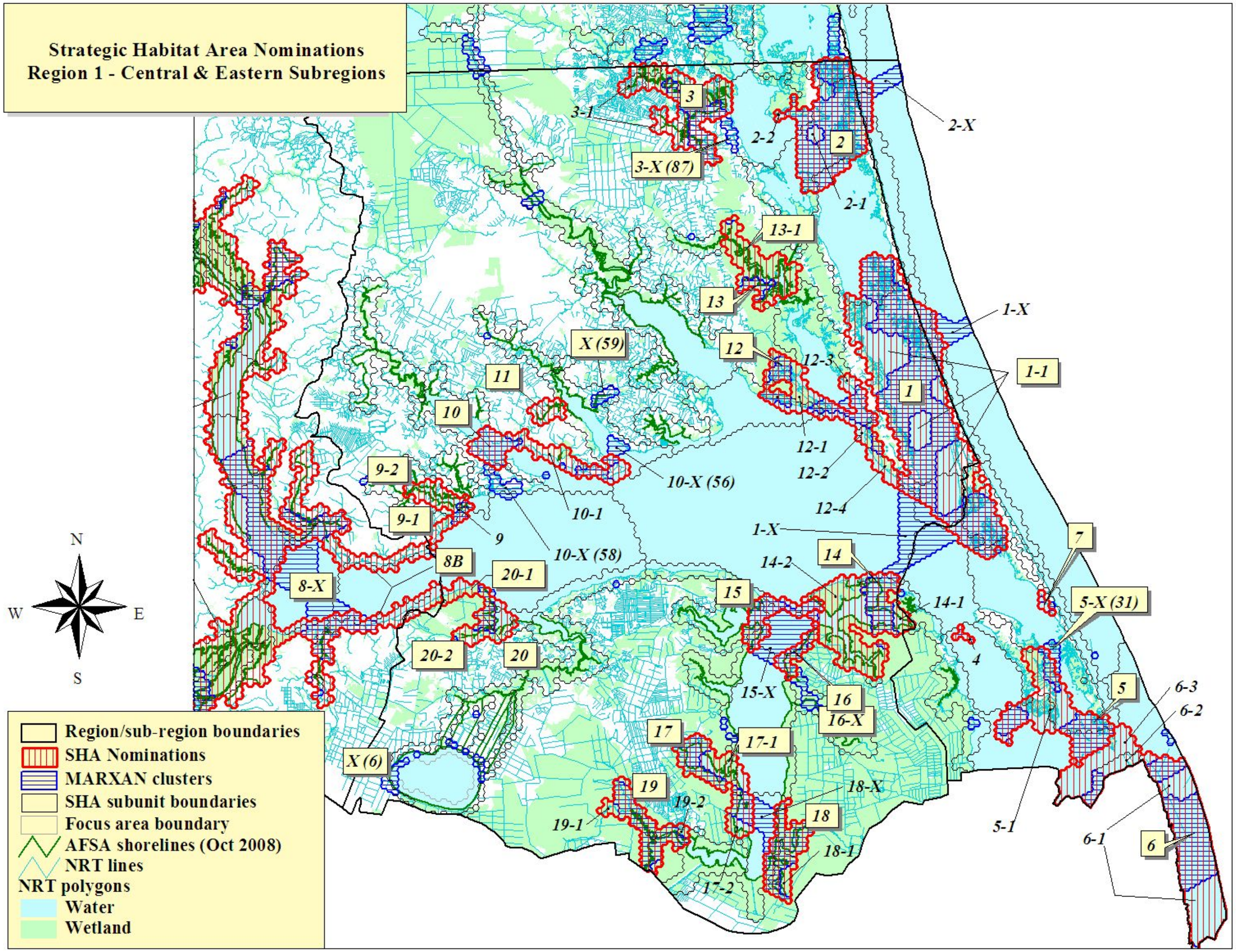
The SHA nominations were re-evaluated for attainment of target representation levels (Table 11). The overall percent of the total area of Natural Resource Targets (NRTs) selected by the computer (Scenario 3) was actually similar to the overall percent selected after expert modification (~ 20%). However, some habitats were greatly exceeded while others were missed. For example, nearly half of all swampy areas (NRT = freshwater forested wetlands - wet) were selected after expert modifications whereas the target level was 30%. On the other hand, representation levels attained for mostly wet forested wetlands were about half the levels targeted in the MARXAN selections. An obvious difference between the MARXAN and expert modifications was the near 100% of riverine soft bottom targets captured within the lower Chowan River. The expert modifications also missed the target representation levels for streams and upper elevation riverine bottoms. However, the missed targets were primarily outside the focus area. Despite the changes, the committee managed to retain a majority of MARXAN clusters, thus ensuring that target representation levels continued to be met.

In rule designation, the artificial hexagon boundaries will need to be modified to ecologically based boundaries. Using hexagon building blocks, it was impossible to fully capture habitat features representing either landward or water-ward boundaries (i.e., 6ft depth contour). For example, the water-ward boundary of the SHA nomination in the Perquimans River (SHA #10) was the 6ft depth contour. The nominations may include some highly altered areas. For example, the Little River nomination includes ditches, canals, and culverts on and above Anadromous Fish Spawning Areas. Groundtruthing to determine precise boundary lines need to be determined prior to any rule designation.

This SHA nomination report for Region 1 will be presented to the Marine Fisheries Commission and CHPP Steering Committee for recognition and approval. Once approved, DMF staff will work to incorporate Region 1 SHAs into WRC's Wildlife Action Plan, DENR's Conservation Planning Tool, Clean Water Management Trust Fund acquisition priorities, and local land use plans. The DMF and WRC will draft specific action plans for each SHA unit that include recommended research, monitoring, and/or non-regulatory enhancement actions. Within each individual SHA action plan, appropriate, BMPs to reduce stormwater runoff, improve water quality, and maintain a natural functioning shoreline can be recommended. These areas could be prioritized for funding with agricultural cost share programs or other restoration grant funding. Special focus will be on enhancing SHA habitat conditions for successful anadromous fish spawning, such as obstruction removal, natural shoreline preservation and restoration, reducing impacts from turbidity and hypoxia. Enhancement actions in the eastern sounds of Region 1 could include marking more subtidal oyster beds as sanctuaries, restoring shallow water nursery habitat, and/or plugging mosquito ditches in tidal wetlands. In addition, DMF and WRC staff will work with other state and federal agencies to implement needed measures that will enhance conditions for anadromous fish spawning. This will directly benefit SHAs, as approximately 73% of all MFC designated AFSAs within Region 1 were selected as SHAs.



Map 6a. Strategic Habitat Area nominations for Region 1. Expert modifications of initial MARXAN cluster also noted (see Table 10).



Map 6b. Strategic Habitat Area nominations for Region 1. Expert modifications of initial MARXAN cluster also noted (see Table 10).

Table 10. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID-ext. (MARXAN clusters)	**Biological data**	**Additional alteration info.**	**Over-riding expert knowledge**	**Other (consensus)**
1 (71)				
1-X (71)				Excluded areas >1 mi from ocean shoreline because nearshore areas were considered more functionally important.
1-X (71)				Excluded deep waters connecting Currituck Sound with the Pam-Albemarle peninsula
1-1				Filled holes in MARXAN cluster for continuity
1-2				Captures possible hard bottom point nearby
2 (94)	Fish data present and excellent ranking		Sara Winslow: nearshore ocean portion include important habitat for sturgeon and striped bass	
2-X (94)				Excluded areas >1 mi from ocean shoreline because nearshore areas were considered more functionally important.
2-1				Filled holes in MARXAN cluster for continuity
2-2				Added for continuity with selected SAV habitats
3 (87)	Fish data present but low ranking		Chad Thomas: important sunfish and largemouth bass spawning area	
3-X (87)				Overland connectivity to Nom. ID 3 with no intervening water areas selected
3-1			Chad Thomas: important sunfish and largemouth bass spawning area	Included all upstream AFSA areas intersecting MARXAN clusters

Table 10. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID-ext. (MARXAN clusters)	**Biological data**	**Additional alteration info.**	**Over-riding expert knowledge**	**Other (consensus)**
4 (33)				Captures northern-most natural oyster rocks
5-X (31)				Omits small selection on opposite side of intracoastal waterway - disconnected with other part of cluster
5 (21, 22, 31)				
5-1		Closed shellfish harvest waters present		Connect MARXAN clusters via contiguous marsh areas containing shell bottom, a PNA and an oyster sanctuary
6 (2, 5, 8)				Includes possible hard bottom point and Platt Shoal
6-1				Connects nearby MARXAN clusters with similar habitat areas and includes an artificial reef
6-2				Connects offshore and inshore selections
6-3				Captures similar habitats nearby and includes the inlet channel - highly important for marine spawning-estuarine nursery species
7 (36,39)				
7-1		Closed shellfish harvest waters present		Captures combination of SAV and shell bottom, a rare habitat classification in this region. Also covers waters off Jockey's Ridge State Park
8-X (55)				>6 ft not important as AFSA

Table 10. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID-ext. (MARXAN clusters)	Biological data	Additional alteration info.	Over-riding expert knowledge	Other (consensus)
8A (connects 11, 19, 24, 26, 27, 29, 34, 35, 37, 38, 40, 44, 46, 47, 49, 55, 62, 63, 64, 66, 68, 69, 72, 73, 76, 77, 78, 79, 81, 82, 83, 84, 85, 86, 88)		Some parts classified impaired due to low IBI, Mercury, or Cadmium		Upstream continuity between MARXAN selections within historically important AFSA through similar habitat areas;
8B (connects 45, 55)	Fish data present and moderate-high ranking	Some parts classified impaired due to dioxins, low IBI, low pH, or Nickel	Sara Winslow: western Albemarle very important nursery area for anadromous species	Downstream extension to capture important anadromous nursery area
9 (48)				
9-1				Complete designation of important anadromous nursery area in western Albemarle Sound
9-2	Fish data points present and low-moderate ranking		Chad Thomas: good fisheries resources present	Capture rest of HU with similar habitat upstream of MARXAN selection except portion with high alteration downstream (i.e. Albemarle Plantation)
10 (53, 54, 56, 58)				
10-X (58)	Fish data present and high ranking	Sara Winslow: undocumented severe alteration (ditching and filling of channels)		
10-X (56)				No SAV on opposite shore, unlike open water selections in #1 and #10
10-1	High ranking fish data just offshore			Capture contiguous SAV habitat
11 (-)	Good fish data downstream	Chad Thomas: relatively low alteration		Switch with X (59)
12 (57, 60, 61)				

Table 10. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID-ext. (MARXAN clusters)	Biological data	Additional alteration info.	Over-riding expert knowledge	Other (consensus)
12-1	Fish data present and moderate ranking			Connection between MARXAN 60 and 61 through similar habitat area
12-2				Connection between MARXAN 57 and 60 through similar habitat area
12-3	Fish data present but low ranking			Extension to end of SAV and shallow water habitat
12-4				Continuity with similar habitat areas
13 (70, 75)				Lot of mostly dry wetlands not selected in other focus area MARXAN clusters
13-1	Fish data present and moderate ranking		Chad Thomas: great freshwater fish habitat near mouth of canal	Capture rest of HU with similar habitats except for canal due to associated alteration (i.e., boat traffic)
14 (31, 71)	Fish data present but low ranking		Chad Thomas: good juvenile fish abundances and habitat	
14-1			Chad Thomas: good juvenile fish abundances and habitat	Continuity with similar habitat areas
14-2	Fish data present but low ranking		Chad Thomas: good juvenile fish abundances and habitat	Continuity with similar habitat areas
15 (41)	Fish data present and high ranking			
15-X (41)		Intracoastal waterway classified impaired due to turbidity		>6 ft not important as AFSA
16 (41)				
16-X (41)				Overland connectivity to #16 via middle portion of stream

Table 10. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID-ext. (MARXAN clusters)	**Biological data**	**Additional alteration info.**	**Over-riding expert knowledge**	**Other (consensus)**
17 (3, 14)				
17-1	Fish data present but low ranking			Continuity with MARXAN clusters (northeast and southeast parts; clusters 14 and 3 respectively)
17-2				Capture all of bay habitat intersecting MARXAN cluster
18 (3)				
18-1				Capture all of lake habitat intersecting MARXAN cluster
18-X (3)		Intracoastal waterway classified impaired due to turbidity		>6 ft not important as AFSA
19 (4)	Fish data present but low ranking		Chad Thomas: Different fish assemblage than mouth of Alligator River	
19-1				Capture remaining 15% of area including small stream area and adjacent wetlands upstream of AFSAs
19-2				Capture remaining 10% of area including adjacent wetlands
20 (42)				
20-1				High cumulative selection frequency, continuity with other Bull Bay habitats
20-2	Fish data similar to adjacent Nom. ID 8B		Sara Winslow: eastern boundary of primary anadromous fish nursery area in Region #1	Continuity with similar habitats in Nom. ID 8

Table 10. Documentation of expert modifications to MARXAN clusters within focus area.

Nom. ID-ext. (MARXAN clusters)	**Biological data**	**Additional alteration info.**	**Over-riding expert knowledge**	**Other (consensus)**
X (6)		Highly altered due to unnatural connection (via canals) with coastal waters and very low pH	Chad Thomas: Anadromous fish minor component of depauperate fish community - not exceptional	
X (59)		Chad Thomas: moderate-severe alteration		

Table 11. Area or distance of natural resource targets contained within SHA nominations. The (+) and (-) indicate over and under target representation levels, respectively.

Feature type	CHPP habitat	Natural Resource Targets	Target	Nominated acres/miles	Nominated % of total
Polygon map origin (acres)	Wetlands	Estuarine forested wetland (mostly wet)	1,413	1,993	21% (+)
		Freshwater forested wetland (mostly dry)	39,030	79,918	15% (+)
		Freshwater forested wetland (mostly wet)	78,471	50,640	13% (--)
		Freshwater forested wetland (wet)	41,410	99,190	48% (+)
		Freshwater marsh (mostly dry)	771	828	8% (+)
		Freshwater marsh (mostly wet)	894	225	5% (--)
		Freshwater marsh (wet)	459	403	18% (--)
		Salt/brackish marsh	8,446	24,984	44% (+)
	SAV	High salinity SAV	2,049	2,660	83% (+)
		Low salinity SAV	14,204	16,046	72% (+)
		SAV in shell bottom	28	37	96% (+)
	Shell bottom	Intertidal shell bottom (high density)	10	8	49% (+)
		Intertidal shell bottom (low density)	4	6	27% (+)
		Subtidal shell bottom (high density)	256	377	88% (+)
		Subtidal shell bottom (low density)	11	66	87% (+)
	Soft bottom	Estuarine soft bottom (>6 ft)	11,855	33,288	8% (+)
		Estuarine soft bottom (0-3ft)	14,662	41,358	42% (+)
		Estuarine soft bottom (3-6ft)	6,826	41,044	36% (+)
		Estuarine soft bottom (ND)	1,354	5,047	56% (+)
		Intertidal estuarine soft bottom	13	75	87% (+)
		Intertidal marine soft bottom	380	788	31% (+)
		Lacustrine soft bottom (ND)	978	1,301	6% (+)
		Marine soft bottom (>6 ft)	5,755	33,663	18% (+)
		Marine soft bottom (0-3ft)	906	4,364	72% (+)
		Marine soft bottom (3-6ft)	447	4,262	57% (+)
		Pond soft bottom (ND)	207	513	7% (+)
		Riverine soft bottom (>6 ft)	712	23,718	100% (+)
		Riverine soft bottom (0-3ft)	406	2,703	100% (+)
		Riverine soft bottom (3-6ft)	137	2,280	100% (+)
		Riverine soft bottom (ND) – lower	3,807	17,078	67% (+)
		Riverine soft bottom (ND) – middle	76	330	26% (+)
		Riverine soft bottom (ND) – upper	18	0	0% (--)
	Hard bottom	Riverine hard bottom	1,116	1,107	99% (--)
	TOTAL polygon area		237,111	490,315	23%
Line map origin (miles)	Wetlands	Wetland edge	707	1,769	50% (+)
	Soft bottom	Non-wetland shoreline	98	449	27% (+)
	Water column	Streams (high elevation)	47	3	0% (--)
		Streams (low elevation)	1,187	719	9% (+)
		Streams (middle elevation)	211	103	3% (--)
	Hard bottom	Hard bottom (possible)	7	9	75% (+)
	TOTAL line distance		2,257	3,043	17%

PROPOSED SHAS

No areas were added or removed as a result of the October 8, 2008 public meeting (Appendix E). The average alteration scores can be interpreted as follows:

- minor alteration = 0-0.5
- low alteration = 0.51-0.99
- moderate alteration = 1.0-1.99
- severe alteration = >2.0

SHA #1: Lower Currituck Sound (75,817 acres) – Map 7a-b
Prominent habitats – Estuarine soft bottom (0-3’, 3-6’ and >6’), freshwater forested wetlands (mostly wet), salt/brackish marsh, riparian wetlands, low salinity SAV, marine intertidal flats and soft bottom (0-3’, 3-6’, and >6’)
Ecological designations - Inland PNA, lands managed for conservation (National Audubon Society), SNHA, coastal fish nurseries
Juvenile fish data - None
Major alterations present - Drainage, canals/boat basins, culverts, ditching, development NPS, agricultural NPS, stormwater permits (new development), major NPDES, wetlands to development
Avg. total alteration score = 0.931
Important notes – None

SHA #2: Bellows Bay to Knotts Island Bay (28,462 acres) – Map 7c
Prominent habitats – Low salinity SAV, salt/brackish marsh, riparian wetlands, estuarine soft bottom (0-3’ and 3-6’)
Ecological designations – Lands managed for conservation (Mackey Island NWR, Currituck NWR), SNHA
Juvenile fish data - None
Major alterations present - Canals/boat basins, culverts, agricultural NPS
Avg. total alteration score = 0.45
Important notes – Sara Winslow stated that nearshore ocean portion was hotspot for sturgeon and striped bass

SHA #3: Northwest River/Tull Bay (20,259 acres) – Map 7c
Prominent habitats – Low salinity SAV, salt/brackish marsh, freshwater forested wetlands (mostly wet), riparian wetlands, estuarine soft bottom (no data), riverine soft bottom, streams
Ecological designations – Inland PNA, AFSA, lands managed for conservation (WRC Northwest River Marsh Gameland), SNHA
Juvenile fish data – Low ranking (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present – Drainage, culverts, Ditching, agricultural NPS, stormwater permits (new development)
Avg. total alteration score = 0.57
Important notes – Chad Thomas stated that area is important spawning location for largemouth bass and sunfish.

SHA #4: Upper Croatan Sound (251 acres) – Map 7d
Prominent Habitats - Subtidal shell bottom (high density)
Ecological Designations - None
Juvenile fish data - None
Major alterations present - Trawling allowed
Avg. total alteration score = 1.00

SHA #5: Cedar Bush Bay, Wanchese marshes, and Broad Creek (20,010 acres) – Map 7d
Prominent Habitats - Salt/brackish marsh, riparian wetlands, subtidal and intertidal shell bottom, high salinity SAV
Ecological Designations - Lands managed for conservation, Significant Natural Heritage Areas, Primary Nursery Areas, and an oyster sanctuary
Juvenile fish data - None
Major alterations present - Drained wetlands, trawling areas
Avg. total alteration score = 0.77 (Region 1 range = 0.01-2.26)
Important notes – Closed shellfish harvesting waters in the upper end of Broad Creek

SHA #6: Oregon Inlet (37,625 acres) – Map 7d
Prominent Habitats – Hard bottom, marine soft bottom (intertidal flats, shallow subtidal flats and deep channels)
Ecological Designations – Crab Spawning Sanctuary, Cape Hatteras National Seashore
Juvenile fish data - None
Major alterations present – trawling allowed, dredging (unmapped), Jetty (unmapped)
Avg. total alteration score = 1.00
Important notes – Inlet channels vital conduit for marine spawning-estuarine nursery species.

SHA #7: Jockey's Ridge State Park (745 acres) – Map 7d
Prominent Habitats – Subtidal shell bottom (high density), SAV in shell bottom, estuarine soft bottom (0-3', 3-6', and >6 ft),
Ecological Designations - Jockey's Ridge State Park, Significant Natural Heritage Area
Juvenile fish data - None
Major alterations present – trawling allowed, stormwater permits (new development), and major NPDES
Avg. total alteration score = 2.05
Important notes – SAV/shell bottom combination needs ground truthing; verify as unique habitat in region.

SHA #8: Chowan and Roanoke River, and western Albemarle Sound (401,233 acres) – Map 7e
Prominent habitats – Streams, freshwater forested wetlands (wet, mostly wet, and mostly dry), riparian wetlands, riparian uplands, riverine soft bottom, riverine hard bottom
Ecological designations - Lands managed for conservation, Significant Natural Heritage Areas, AFSAs
Juvenile fish data – moderate to high ranking (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present - Drained wetlands, impoundments, channelization, agricultural NPS, major NPDES, minor NPDES, converted wetlands
Avg. total alteration score = 0.36
Important notes - Selected entire Chowan and Roanoke for their historical importance to river herring and other anadromous species, and to maintain continuity within the migratory spawning area.
Sara Winslow: western Albemarle Sound very important nursery area for anadromous fish.

SHA #9: Yeopim River (6,711 acres) – Map 7f
Prominent habitats – Low salinity SAV, estuarine soft bottom (0-3', 3-6', and >6'), freshwater forested wetlands (mostly dry), riparian wetlands
Ecological designations – Lands managed for conservation, Significant Natural Heritage Areas, AFSAs
Juvenile fish data – Low to moderate ranking (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present – culverts, canals/boat basins, impoundments, riparian uplands to agriculture

Avg. total alteration score = 0.2678
Important notes - Chad Thomas stated that good fishery resources are present

SHA #10: Perquimans River from Grassy Point to Stevenson Point (12,180 acre) – Map 7f
Prominent habitats – Low salinity SAV, freshwater forested wetlands (wet), riparian wetlands, estuarine soft bottom (0-3’, 3-6’, and >6’)
Ecological designations – SNHA, AFSAs
Juvenile fish data – Moderate ranking (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present - culverts, ditching, agricultural NPS, stormwater permits (new development),
Avg. total alteration score = 0.917
Important notes - none

SHA #11: Little River at Deep Creek (2,610 acres) – Map 7f
Prominent habitats - Streams, freshwater forested wetlands (wet, mostly dry), riparian wetlands, riverine soft bottom, shallow estuarine soft bottom
Ecological designations - AFSAs
Juvenile fish data – moderate ranking downstream (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present – Culverts, ditching, agricultural NPS
Avg. total alteration score = 0.780
Important notes – Chad Thomas stated Deep Creek in better condition than similar creeks in Little River.

SHA #12: Lower North River (18,022 acres) – Map 7a-b
Prominent habitats – Low salinity SAV, Estuarine soft bottom (0-3’, 3-6’, and >6 ft), freshwater forested wetlands (mostly wet), riparian wetlands
Ecological designations – Inland PNA, SNHAs
Juvenile fish data – Low-moderate ranking (Atlantic croaker, striped bass, white perch)
Major alterations present - Drainage, culverts, agricultural NPS, stormwater permits (new development)
Avg. total alteration score = 0.3642
Important notes – none

SHA #13: Upper North River (12,304 acres) – Map 7a
Prominent habitats - Freshwater forested wetlands (mostly wet, mostly dry), estuarine soft bottom (0-3’, 3-6’, and >6 ft)
Ecological designations – AFSA, lands managed for conservation (WRC North River Gameland), SNHA
Juvenile fish data – Moderate ranking (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present - None
Avg. total alteration score = 0.08
Important notes – Chad Thomas stated that area near canal mouth was great fish habitat.

SHA #14, 15, & 16: Lower Alligator River, East Lake (25,230, 6,587, & 3,231 acres, respectively) – Map 7g
Prominent habitats - Salt/brackish marsh, freshwater forested wetlands (mostly wet), riparian wetlands, low salinity SAV
Ecological designations - Lands managed for conservation, Significant Natural Heritage Areas, AFSA, Inland PNAs, and ORW
Juvenile fish data – Moderate ranking (Atlantic croaker, striped bass, white perch)
Major alterations present - None
Avg. total alteration score = 0.01-0.04

Important notes –

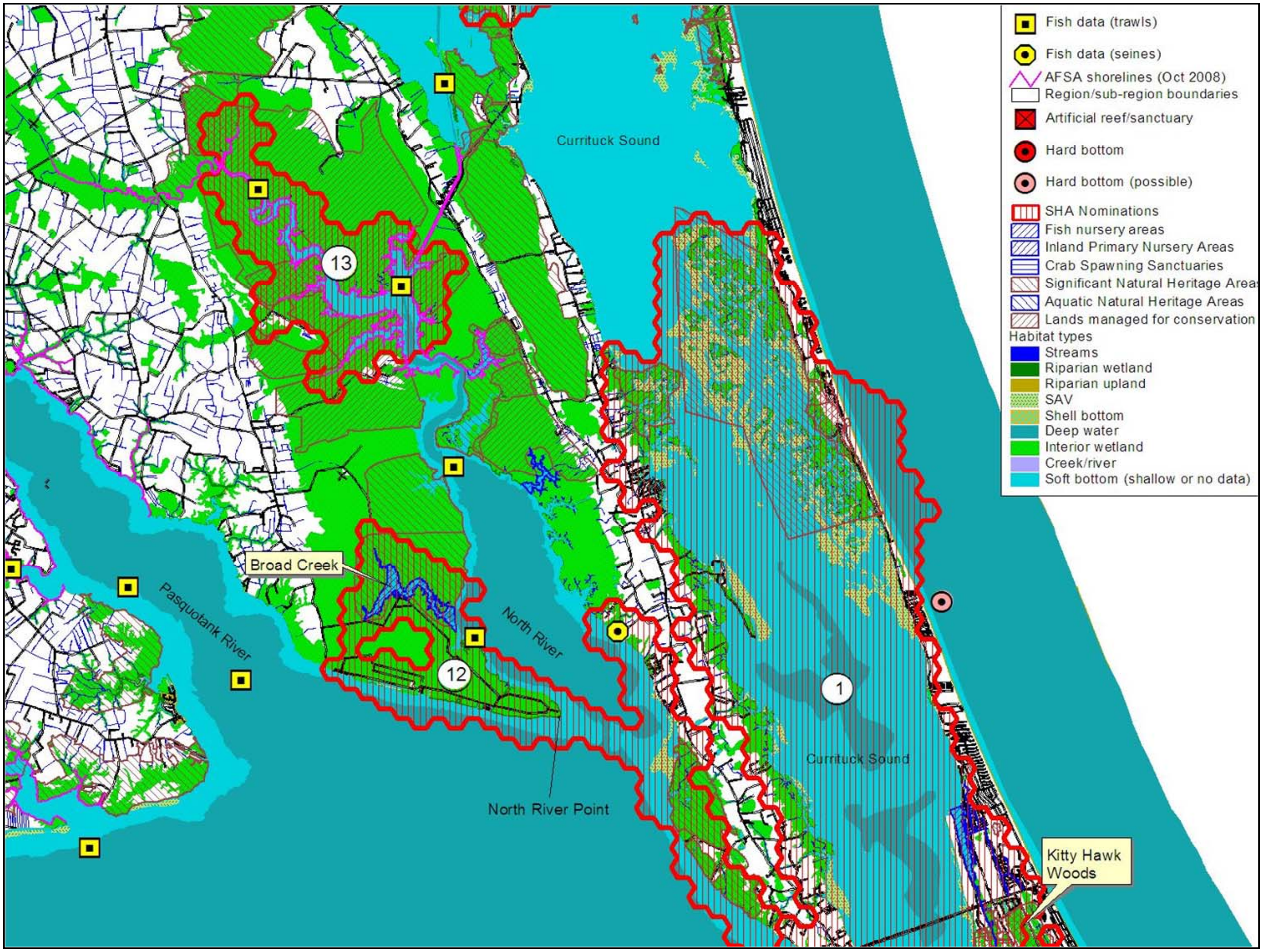
SHA #17: Alligator River at Big Frying Pan (13,174 acres) – Map 7h
Prominent habitats – Freshwater forested wetlands (mostly dry), riparian wetlands, estuarine soft bottom (shallow, deep and no data)
Ecological designations - AFSAs, SNHA, Buck Ridge Coastal Reserve, Pocosin Lake NWR
Juvenile fish data – Low (Atlantic croaker, striped bass, white perch)
Major alterations present - Drainage
Avg. total alteration score = 0.1541
Important notes – none

SHA #18: Swan and Whipping Creek (9,943 acres) – Map 7h
Prominent habitats - Freshwater forested wetlands (mostly dry), riparian wetlands, estuarine soft bottom (shallow, deep), and lacustrine bottom
Ecological designations – AFSA, SNHA, Alligator River NWR
Juvenile fish data – None
Major alterations present - Culverts
Avg. total alteration score = 0.0554
Important notes – none

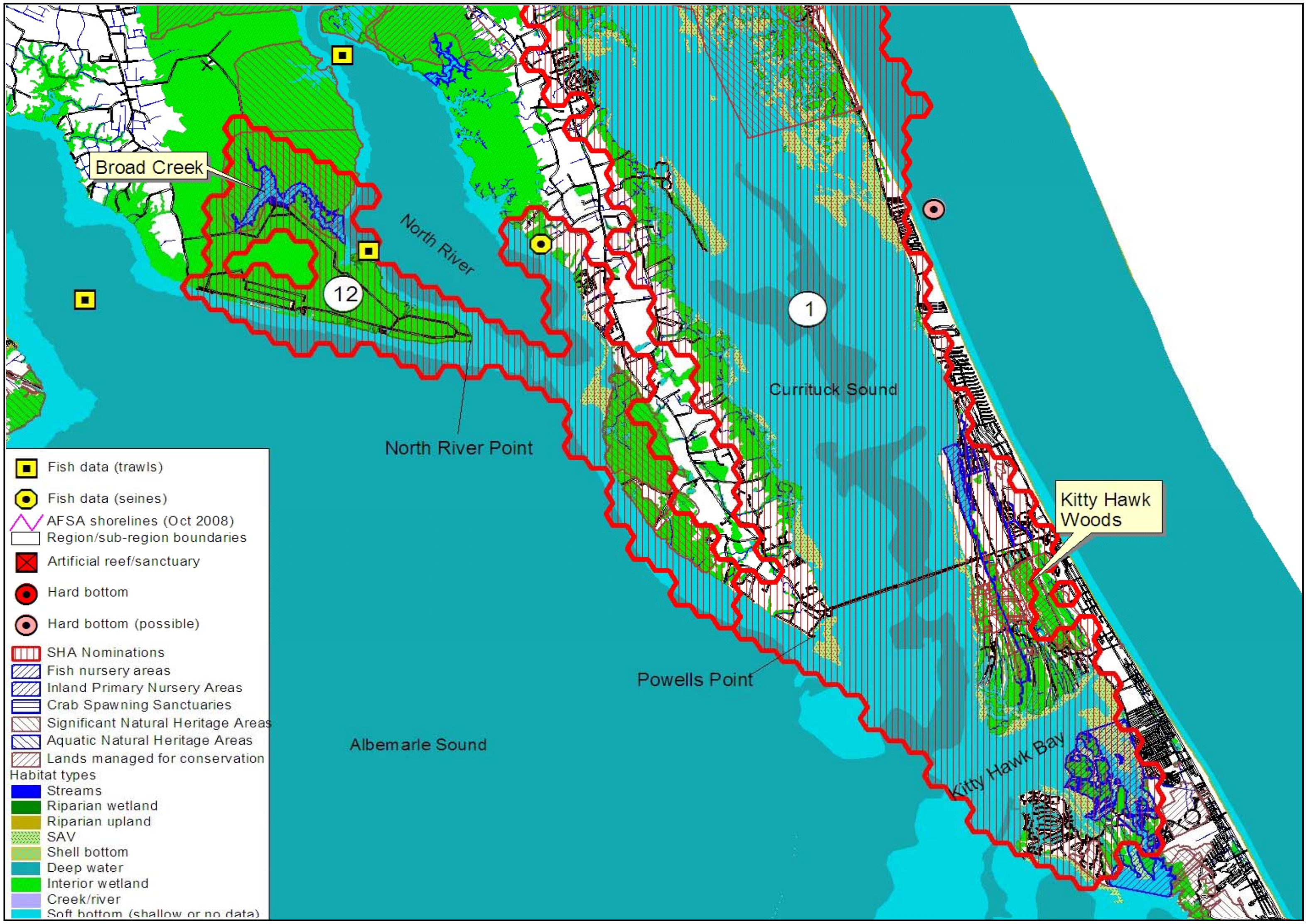
SHA #19: Northwest/Southwest Fork (10,583 acres) – Map 7h
Prominent habitats - Freshwater forested wetlands (mostly dry), riparian wetlands, estuarine soft bottom (shallow, deep and no data)
Ecological designations - AFSA, SNHA, Buckridge Coastal Reserve, Pocosin Lakes NWR
Juvenile fish data – Low ranking (Atlantic croaker, striped bass, white perch)
Major alterations present - Culverts
Avg. total alteration score = 0.0557
Important notes – Chad Thomas stated there is a different fish assemblage here than in mouth of Alligator River

SHA #20: Laurel Point to Bull Bay (9,073 acres) – Map 7i
Prominent habitats - Freshwater forested wetlands (mostly wet, mostly dry), riparian wetlands, estuarine soft bottom (0-3’, 3-6’, and >6’)
Ecological designations – AFSA, lands managed for conservation (NCSU Bull Neck Research Forest), SNHA
Juvenile fish data – Similar to adjacent nomination #8 (Atlantic croaker, blueback herring, striped bass, white perch)
Major alterations present - Culverts
Avg. total alteration score = 0.206
Important notes – Sara Winslow stated area is eastern boundary of primary anadromous fish nursery area in region

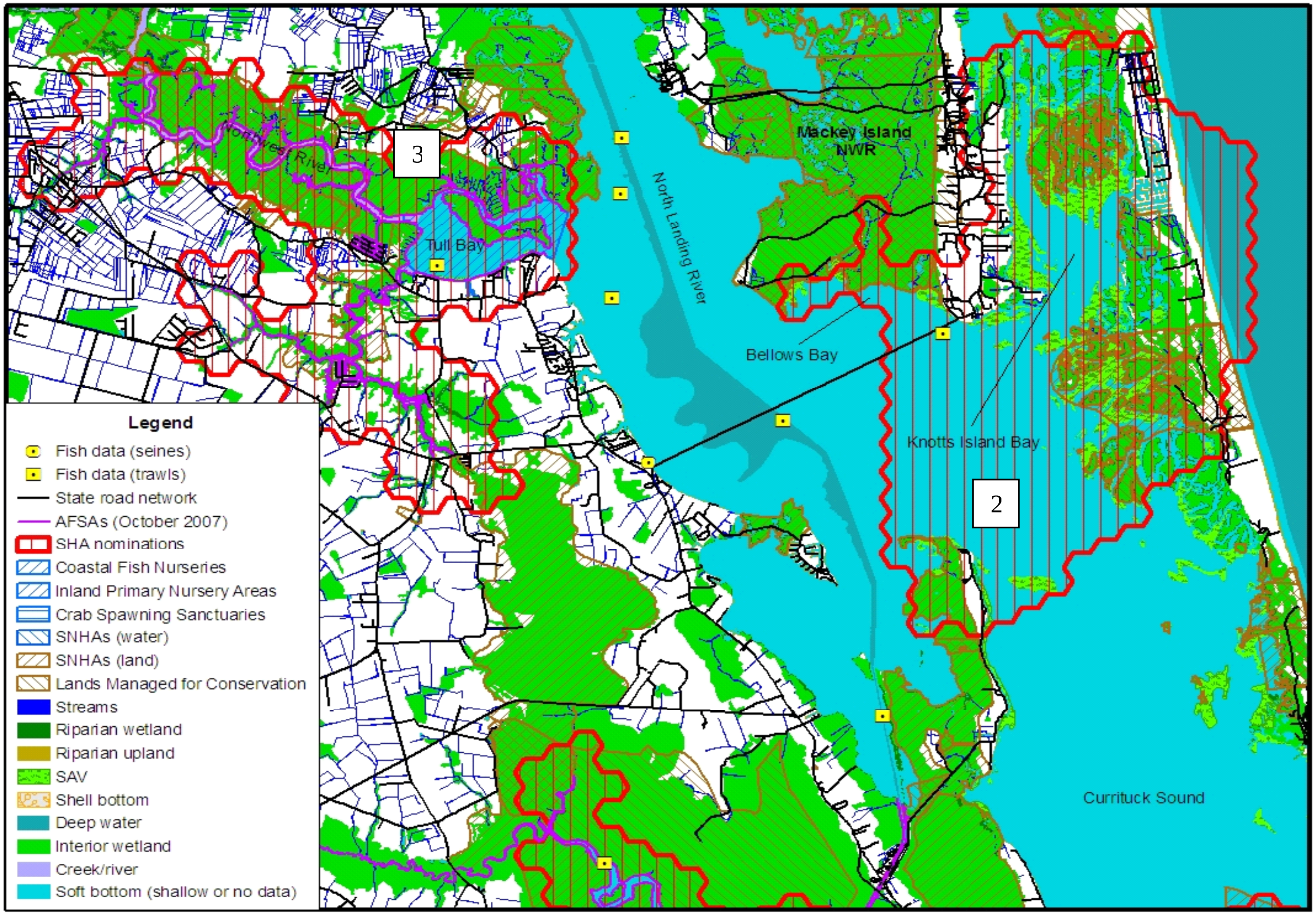
Region 1 Strategic Habitat Areas 3/20/2009



Map 7a. Region 1 Strategic Habitat Areas numbers 1 (upper), 12, and 13.

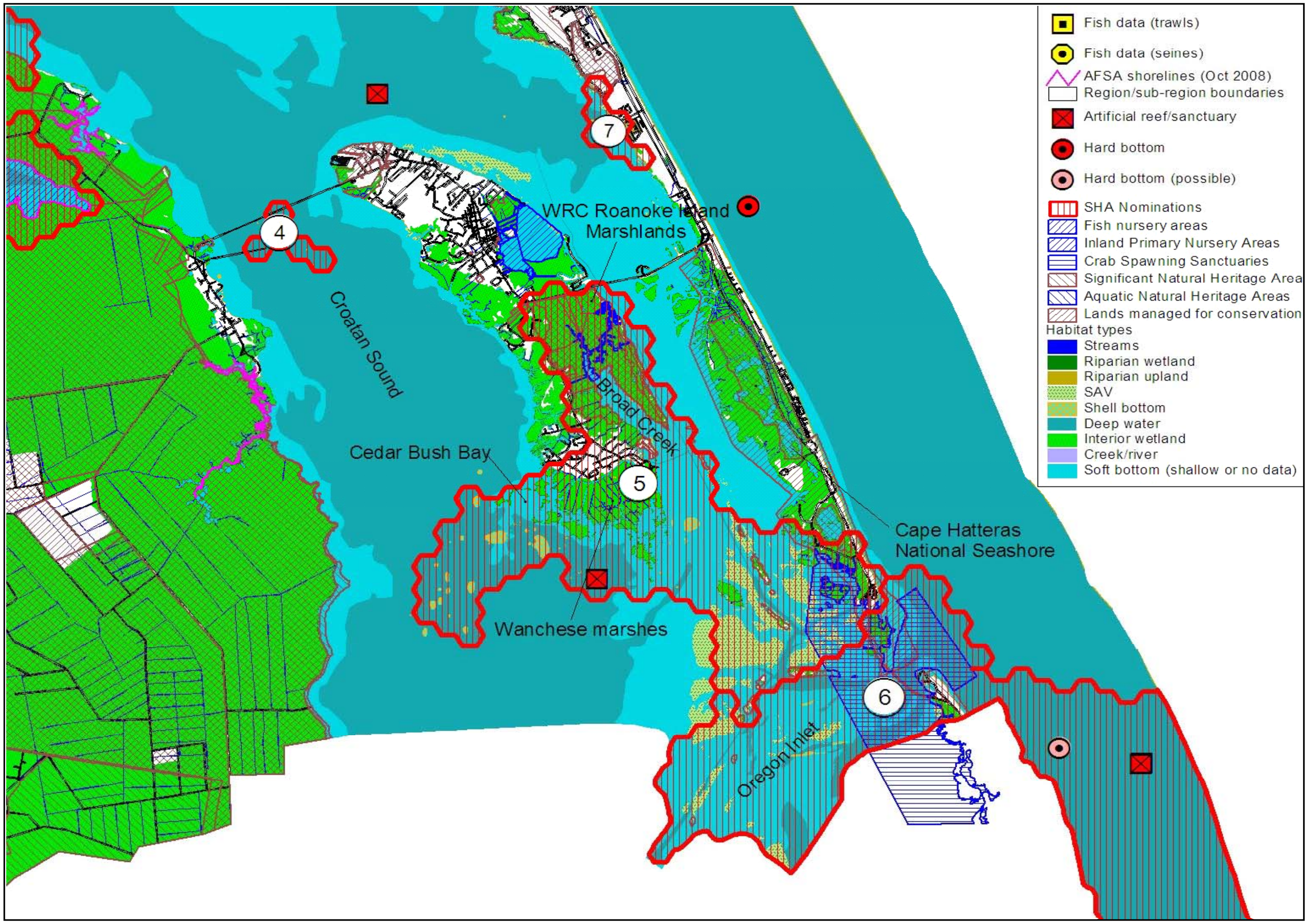


Map 7b. Region 1 Strategic Habitat Areas numbers 1 (lower) and 12.

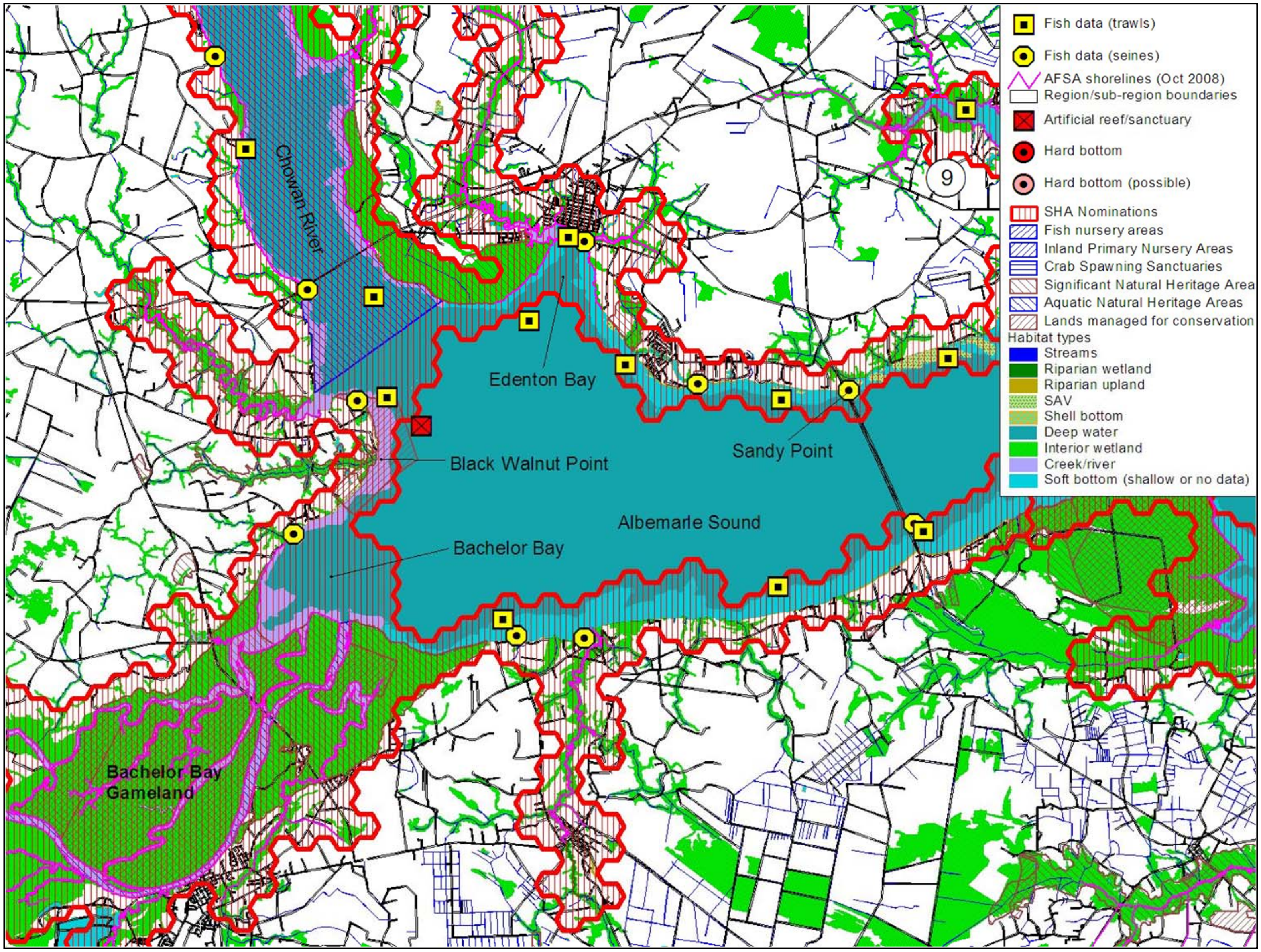


Map 7c. Region 1 Strategic Habitat Areas numbers 2 and 3.

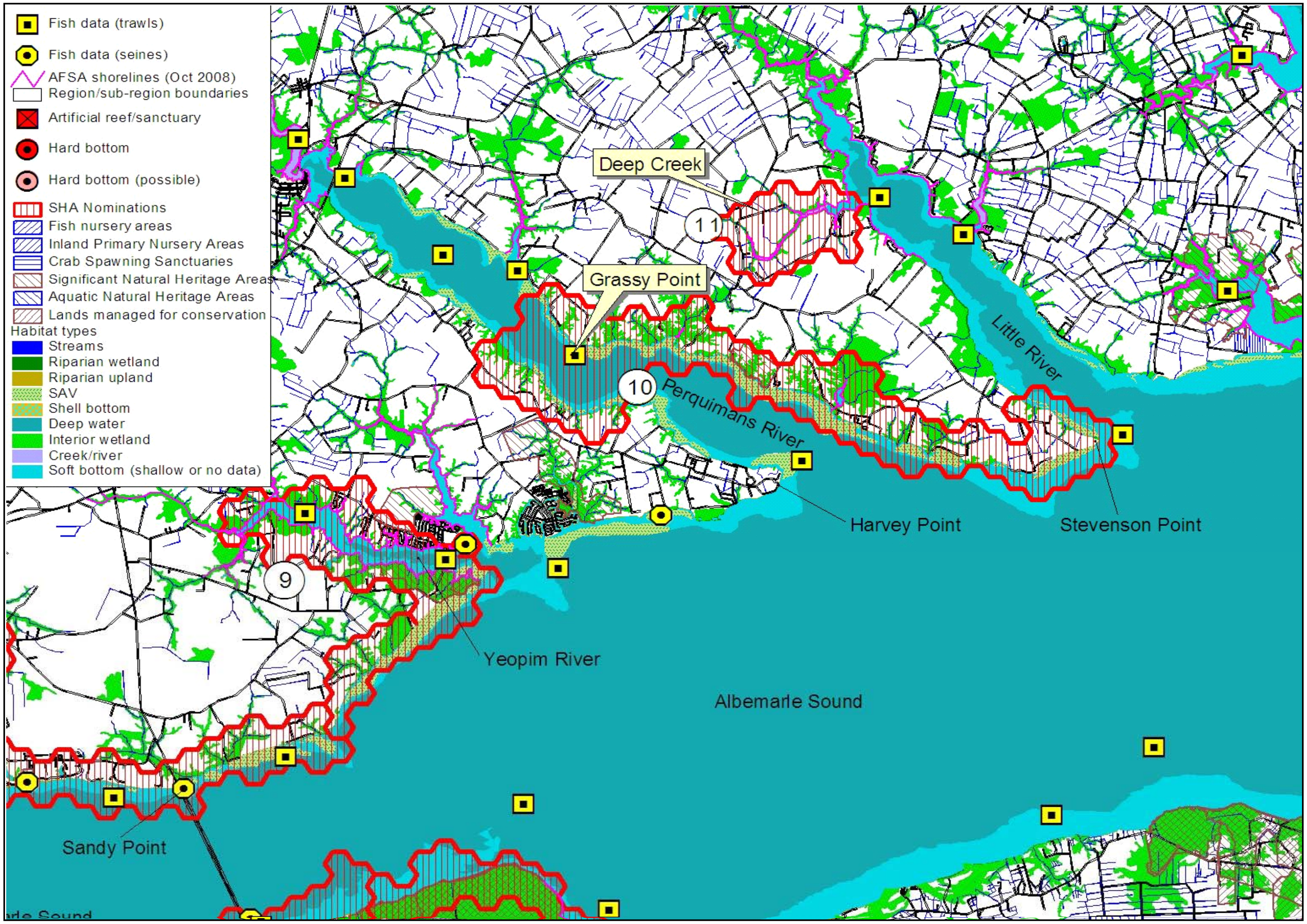
Region 1 Strategic Habitat Areas 3/20/2009



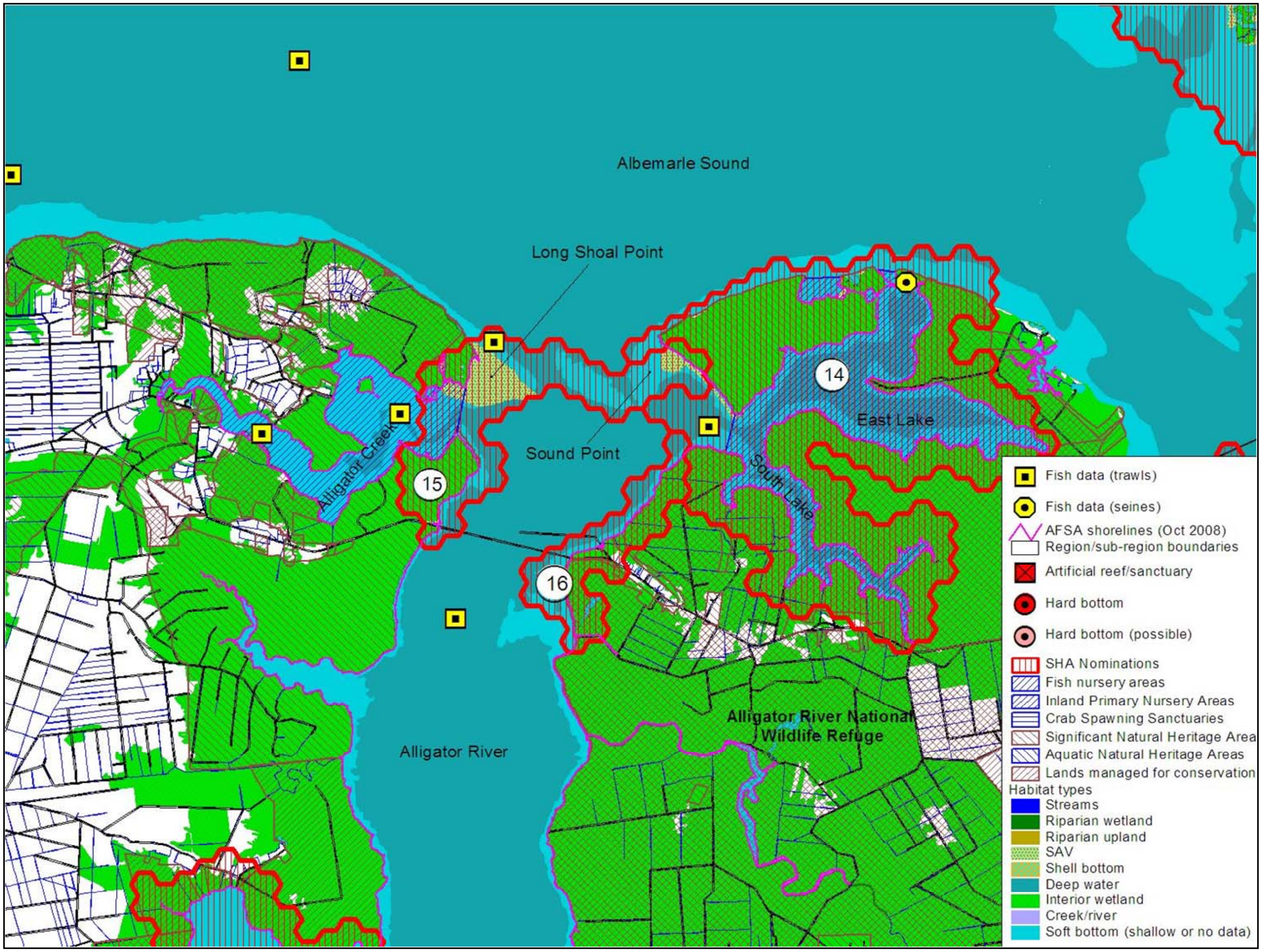
Map 7d. Region 1 Strategic Habitat Areas numbers 4, 5, 6, and 7.



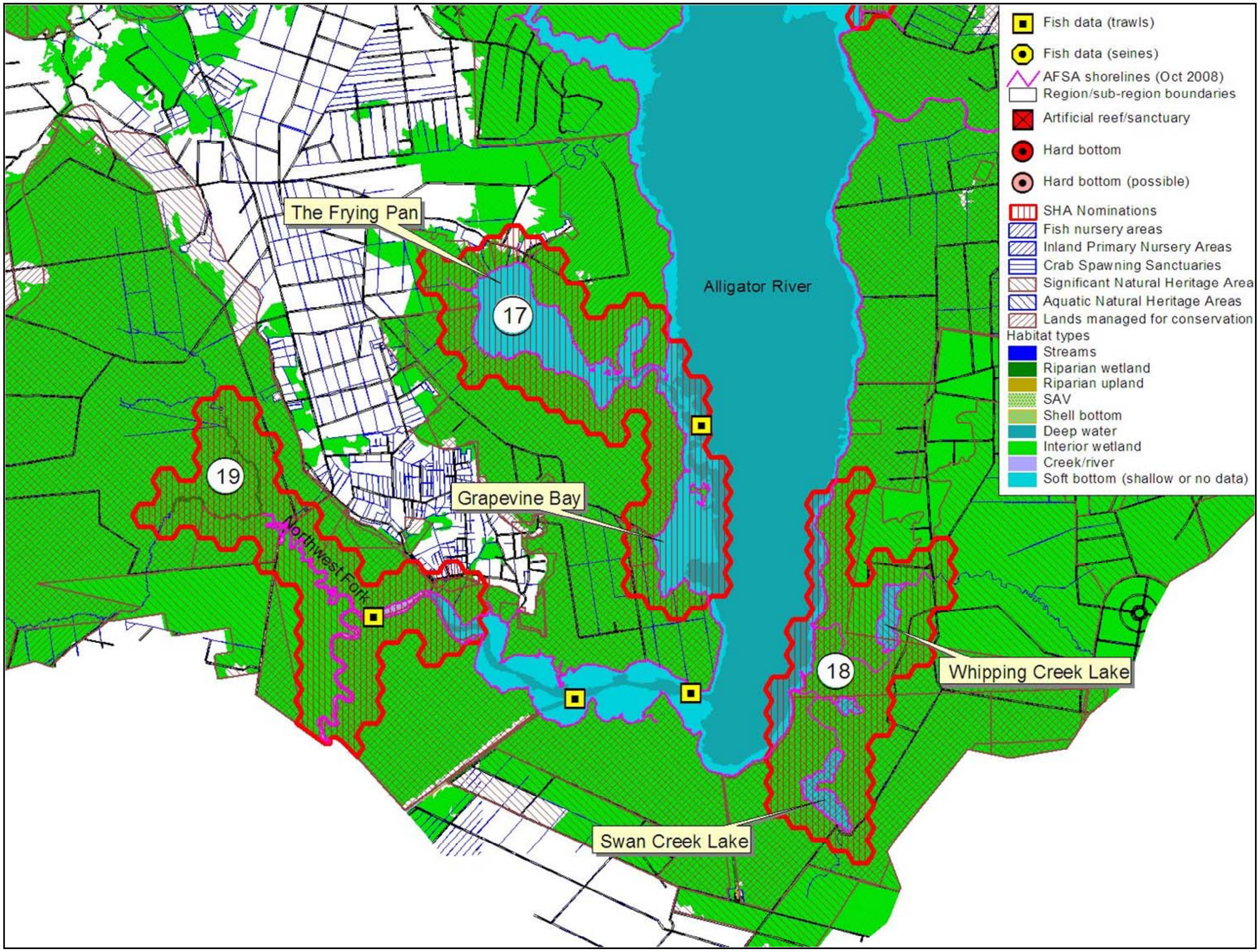
Map 7e. Region 1 Strategic Habitat Areas number 8.



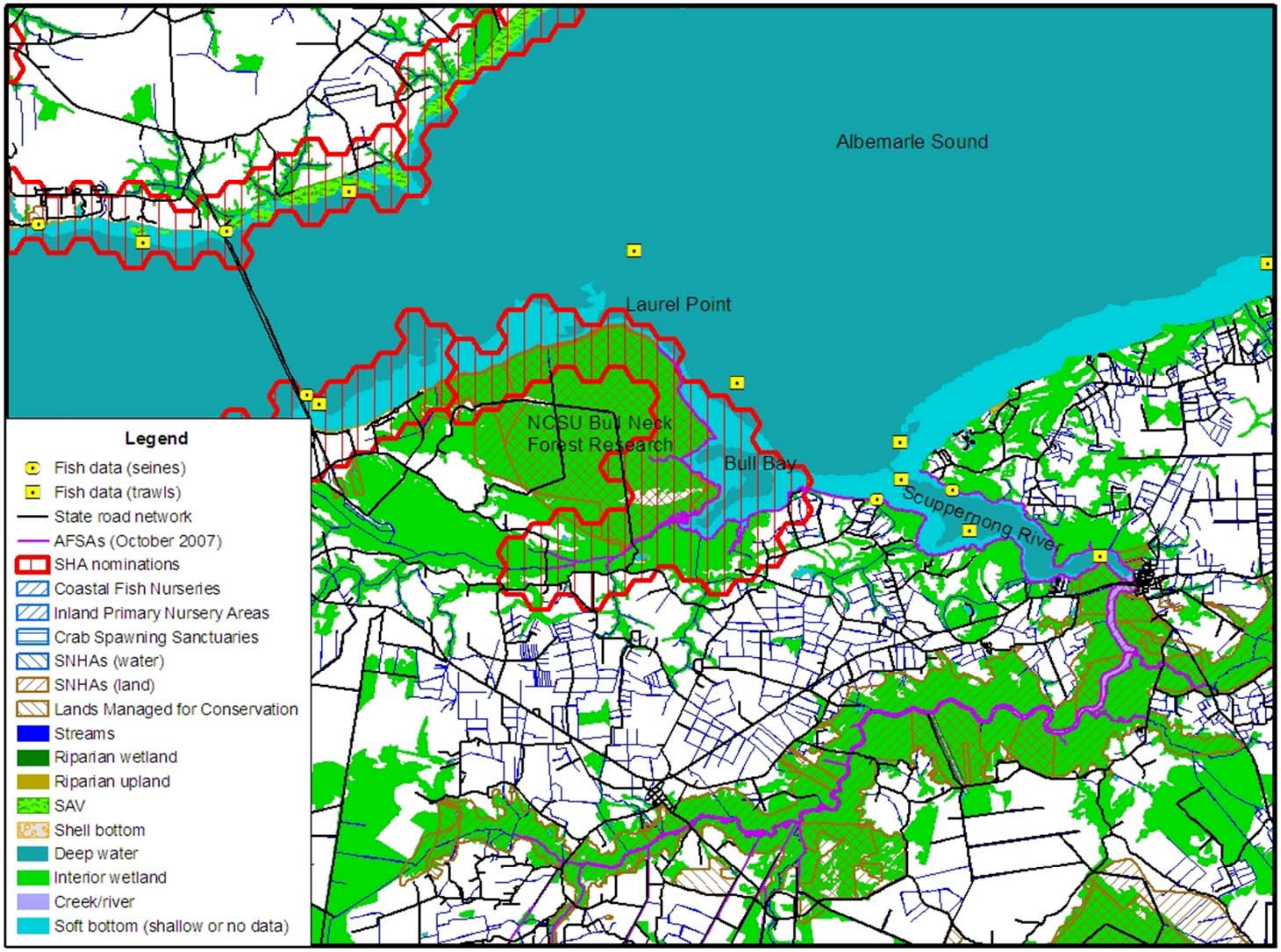
Map 7f. Region 1 Strategic Habitat Areas numbers 9, 10, 11.



Map 7g. Region 1 Strategic Habitat Areas numbers 14, 15, 16.



Map 7h. Region 1 Strategic Habitat Areas numbers 17, 18, 19.



Map 7i. Region 1 Strategic Habitat Areas number 20.

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http://demog.state.nc.us/

APPENDIX A: DATA/INFORMATION DIRECTORY

SHA Nominations - G:\CHPPs\SHA Related\Region 1\R1_SHA_nominations.shp
Decision support maps - G:CHPP\SHA Related\Region 1\Map documents*.pdf
MARXAN input files[2] - G:CHPP\SHA Related\Region 1\Inputs and outputs\MARXAN input files.xls

Data theme	G:\CHPPs\SHA Related\Region 1\Inputs and outputs\
Region/subregion boundaries	R1_states_subregions.shp
Hydrologic units	R1_hydrologic_units.shp
Hexagons (0.5 km^2)	MARXAN files\R1_hexagons.shp
Focus area	MARXAN files\R1_focus_area_500m.shp
MARXAN selections	MARXAN files\R1_MARXAN_selections.shp
Habitat types for alteration	natural resource targets\R1_habitat_types_for_alteration.shp
Natural resource targets (polygons)	natural resource targets\R1_nrt_polygons.shp
Natural resource targets (lines)	natural resource targets\R1_nrt_lines.shp
Culverts (partial obstructions)	alteration factors\R1_downstream_1st_culvert.shp, R1_culverts.shp
Storm gates and locks (partial obstructions)	alteration factors\R1_diked_impounded_gated.shp
Impoundments (fully obstructed)	alteration factors\R1_diked_impounded.shp, R1_dams.shp
Channelized streams	alteration factors\R1_channelization.shp
Dredge channels	alteration factors\R1_coe_dredge_channels.shp
Drained wetlands	alteration factors\R1_partially_drained.shp
Ditched streams	alteration factors\R1_ditched_streams.shp
Canals and boat basins	alteration factors\R1_canals_boat_basins.shp
Industrial waste pond	alteration factors\R1_industrial_waste_ponds.shp
NPDES sites	alteration factors\R1_NPDES_sites.shp
%Developed	alteration factors\R1_lulc2001_by_hu.shp
%Agriculture	alteration factors\R1_lulc2001_by_hu.shp
Development change	alteration factors\R1_stormwater_permits.sbx
Wetlands lost to development	alteration factors\R1_altered_lulc_by_nrt_polygons.shp
Wetland lost to agriculture	alteration factors\R1_altered_lulc_by_nrt_polygons.shp

[2] See Appendix B for creation process

Data theme	**G:\CHPPs\SHA Related\Region 1\Inputs and outputs**
Riparian upland development	alteration factors\R1_altered_lulc_by_nrt_lines.shp
Riparian upland agriculture	alteration factors\R1_altered_lulc_by_nrt_lines.shp
DWQ impairment	alterations factors\R1_draft_impaired_water_2008.shp
Bottom disturbing fishing gear	alteration factors\R1_bottom_disturbing_fishing_gear.shp
Municipal stormwater outfalls	alteration factors\R1_municipal_stormwater_outfalls.shp
Stormwater outfalls - area H2 shoreline survey	alteration factors\R1_H2_stormwater_outfalls.shp
Animal operations	alteration factors\R1_animal_operations.shp (not used)
Surface water intakes	alteration factors\R1_surface_water_intakes.shp (not used)
Jetties	alteration factors\R1_jetties.shp (not used)
Railroads	alteration factors\R1_NC_railroads.shp (not used)
Anadromous Spawning Areas	Corroborating information \R1_AFSA_shorelines.shp
Blue crab spawning sanctuaries	Corroborating information \R1_crab_spawning_sanctuaries.shp
Oyster sanctuaries	Corroborating information\R1_nrt_points.shp
Estuarine fish nurseries (i.e., PNAs)	Corroborating information \R1_coastal_nursery_areas.shp
Freshwater fish nurseries (i.e., inland PNAs)	Corroborating information \R1_inland_nursery_areas.shp
Open shellfish harvesting waters	Not used
Significant Natural Heritage Areas (aquatic and terrestrial)	Corroborating information \R1_snha_terrestrial.shp, R1_snha_aquatic.shp
Lands managed for conservation	Corroborating information \R1_conservation_lands.shp
Juvenile anadromous and freshwater fish (i.e., river herring, shad, sturgeon, white perch)	Corroborating information \R1_fish_data_trawl.shp, R1_fish_data_seine.shp
Outstanding Resource Waters and High Quality Waters	Corroborating information \R1_orw_hqw.shp (not used)

Data theme	**G:\CHPPs\SHA Related\Region 1\Inputs and outputs**
Fish and benthic bioclassification (freshwater streams only); excellent IBI or EPT	Not used
Juvenile estuarine fish (i.e., spot, croaker, flounder)	Not used
Shellfish densities (i.e., clams, oysters, bay scallops)	Not used (part of NRTs)

APPENDIX B: PREPARING THE MARXAN FILES

Going from the data/information directory to the MARXAN files requires operations in both ArcMap and Access. The following paragraphs describe the process of creating the necessary files for running MARXAN (see http://www.uq.edu.au/marxan/docs/Marxan_User_Manual_2008.pdf).

TRANSLATOR

The translator table is created to link ID numbers to Natural Resource Target names. The MARXAN program uses only ID numbers to represent the NRTs. The table also contains the total area or distance of each NRT. Representation levels for running program scenarios are calculated from this table and pasted into the Spec.dat file (in ‘Target’ field).

SPEC.DAT

The spec.dat file is used by MARXAN to set representation levels for each target. In the sample table below, the representation level is the ‘Target’ field.

id	type	target	spf
1	0	2826.74	1000
2	0	0.00	1000
3	0	130099.88	1000
4	0	156941.70	1000
5	0	82819.55	1000
6	0	2571.05	1000
7	0	1788.37	1000
8	0	918.95	1000
9	0	16891.78	1000
10	0	2561.43	1000

PUDATA.DAT

The pudata.dat file is used by MARXAN to set the cost of each hexagon (‘id’ field) on the modeling grid and the initial seeding (sample table below).

id	cost	status
1	4.1097	0
2	4.1097	0
3	2.5000	0
4	3.2057	0
5	3.0639	0
6	2.5745	0
7	2.6470	0
8	2.5601	0
9	2.5705	0
10	2.5989	0

The ‘status’ field determines the initial seeding. Status variables include:

0 = The hexagon is not guaranteed to be in the initial or ‘seed’ reserve. However it still may be. It’s chance of being included in the initial reserve is exactly the ‘starting proportion’ from the parameter input file.
1 = The hexagon will be included in the ‘seed’ reserve or the initial reserve. It may or may not be in the final reserve.
2 = The hexagon is fixed in the reserve. It starts in the initial reserve and cannot be removed.
3 = The hexagon is fixed outside of the reserve. It is not included in the initial reserve and cannot be added.

The ‘cost’ field, in this case, is synonymous with total alteration score. The cost field was, by far, the most complicated to determine of all the MARXAN variables. See Appendix D for a sample calculation. For Region 1 cost values, some overlay (i.e., union) operations must be performed on the raw alteration factor coverages listed in the data/information directory.

Step 1 - The water-based factors are combined to form one coverage with the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. Drained – value of 1 for drained wetland
3. Dredged – value of 1 for dredged channel
4. Canal_ba value of 1 for canals or boat basin
5. Ind_waste - value of 1 for industrial waste pond
6. Trawl_dr value of 1 for trawling and/or dredging allowed
7. Impound - value of 1 for impounded
8. Obstruct - value of 1 for lock obstructed
9. Culvert - value of 1 for culvert obstructed
10. Channel - value of 1 for channelized riparian zone
11. Ditch - value of 1 for ditched stream
12. Wet_dev - value of 1 for wetland converted to development
13. Wet_ag - value of 1 for forested wetland converted to agriculture
14. Up_dev - value of 1 for riparian upland converted to development
15. Up_ag - value of 1 for riparian upland converted to agriculture
16. Acres – area of unique combination of ID and set of alterations present

Note: For hexagons intersecting multiple alteration factors, there may be more than one row for one hexagon ID – where the two or more factors overlap, and where they do not.

Step 2 – Overlay the product of Step 1 with R1_habitat_types_for_alteration_coverage to include the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. Drained – value of 1 for drained wetland
3. Dredged – value of 1 for dredged channel
4. Canal_ba - value of 1 for canals or boat basin
5. Ind_waste - value of 1 for industrial waste pond
6. Trawl_dr - value of 1 for trawling and/or dredging allowed
7. Impound - value of 1 for impounded
8. Obstruct - value of 1 for lock obstructed
9. Culvert - value of 1 for culvert obstructed
10. Channel - value of 1 for channelized riparian zone
11. Ditch - value of 1 for ditched stream
12. Wet_dev - value of 1 for wetland converted to development
13. Wet_ag - value of 1 for forested wetland converted to agriculture
14. Up_dev - value of 1 for riparian upland converted to development

15. Up_ag - value of 1 for riparian upland converted to agriculture
16. Acres (recalculated) – area of each combination of ID, set of alterations present, and habitat type
17. Chpp_habit – habitat types used to assign alteration factors

Step 3 – Replace all 1's in the Product of Step 2 with the acres. Export this file to a database (i.e., MS Access) to perform a query that divides the acres of habitat type X overlapping factor Y by the total acres of habitat type X. The resulting proportion is used in the equation featured prominently in Appendix D ('extent' variable). The extent values for the land-based alteration factors are determined next.

Step 4 – Combine the hydrologic units, stormwater permits, and NPDES coverage to contain the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. HU – hydrologic unit code
3. Acres – area for combination of ID and HU
4. St_permit – number of stormwater permits
5. NPDES1 – number of major NPDES sites
6. NPDES2 – number of minor NPDES sites

Step 5 – Combine the hydrologic units and R1_lulc2001_by_hu coverage to include the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. HU – hydrologic unit code
3. Acres – area for combination of ID and HU
4. Dev_prop – proportion of [ID, HU] combination in developed land uses (0-1)
5. Agri_prop – proportion of [ID,HU] combination in agricultural land uses (0-1)

Step 6– combine the products of Steps 4 and 5 to include the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. HU – hydrologic unit code
3. Acres – area for combination of ID and HU
4. St_permit – number of stormwater permits
5. NPDES1 – number of major NPDES sites
6. NPDES2 – number of minor NPDES sites
7. Dev_prop – proportion of [ID, HU] combination in developed land uses (0-1)
8. Agri_prop – proportion of [ID,HU] combination in agricultural land uses (0-1)

Step 7 – Overlay the product of Step 6 with R1_habitat_types_for_alteration_coverage to include the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. HU – hydrologic unit code
3. Acres – area for combination of ID and HU
4. St_permit – number of stormwater permits
5. NPDES1 – number of major NPDES sites
6. NPDES2 – number of minor NPDES sites
7. Dev_prop – proportion of [ID, HU] combination in developed land uses (0-1)
8. Agri_prop – proportion of [ID,HU] combination in agricultural land uses (0-1)
9. Chpp_habit – habitat types used to assign alteration factors
10. Acres2 – area of combination of ID, HU, and Chpp_habit

Step 8 – Determine the number of stormwater permits, major NPDES and minor NPDES *by hexagon* for the product of Step 7. This will require a calculation using the (example) formula: (Acres of HU X/total acres)*(number stormwater permits in HU X) + (Acres of HU Y/total acres)*(number of stormwater permits in HU Y). Repeat this for each hexagon and factor.

Step 9 – Determine the proportion of developed and agricultural land uses *by hexagon* for the product of Step 7. This will require a calculation using the (example) formula: (Acres of HU X/total acres)*(proportion development in HU X) + (Acres of HU Y/total acres)*(proportion development in HU Y). Repeat this for each hexagon and factor. This completes the extent determination for land-based alteration factors.

Step 10 – Combine the product of Steps 3, 8, and 9 to form a database table with the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. Chpp_habit – habitat types used to assign alteration factors
3. Acres – area of combination of ID and Chpp_habit
4. Drained – proportion of drained wetland
5. Dredged – proportion of dredged channel
6. Canal_ba - proportion of canals or boat basin
7. Ind_waste - proportion of industrial waste pond
8. Trawl_dr - proportion of trawling and/or dredging allowed
9. Impound - proportion of impounded
10. Obstruct - proportion of lock obstructed
11. Culvert - proportion of culvert obstructed
12. Channel - proportion of channelized riparian zone
13. Ditch - proportion of ditched stream
14. Wet_dev - proportion of wetland converted to development
15. Wet_ag - proportion of forested wetland converted to agriculture
16. Up_dev - proportion of riparian upland converted to development
17. Up_ag - proportion of riparian upland converted to agriculture
18. St_permit – proportion of stormwater permits
19. NPDES1 – proportion of major NPDES sites
20. NPDES2 – proportion of minor NPDES sites
21. Dev_prop – proportion of developed land uses
22. Agri_prop – proportion of agricultural land uses

Step 11 – Query the total area of habitat in each hexagon ID.

Step 12 – Query the products of Steps 10 and 11 to calculate the proportion of habitat X among all habitats in hexagon Y. This will be the 'portion' variable in the alteration equation (see Appendix D). The table should have the following fields:

1. ID - unique identifier for individual hexagons on modeling grid
2. Chpp_habit - habitat types used to assign alteration factors
3. Portion – proportion of habitat X among all habitats in hexagon Y.

Step 13 – Create a table with the following field for each Chpp_habitat:

1. Chpp_habit - habitat types used to assign alteration factors
2. Drained – alteration factor rating for drained wetlands
3. Dredged – alteration factor rating for dredged channel
4. Canal_ba - alteration factor rating for canals or boat basin
5. Ind_waste - alteration factor rating for industrial waste pond
6. Trawl_dr - alteration factor rating for trawling and/or dredging allowed
7. Impound - alteration factor rating for impounded
8. Obstruct - alteration factor rating for lock obstructed
9. Culvert - alteration factor rating for culvert obstructed

10. Channel - alteration factor rating for channelized riparian zone
11. Ditch - alteration factor rating for ditched stream
12. Wet_dev - alteration factor rating for wetland converted to development
13. Wet_ag - alteration factor rating for forested wetland converted to agriculture
14. Up_dev - alteration factor rating for riparian upland converted to development
15. Up_ag - alteration factor rating for riparian upland converted to agriculture
16. St_permit – alteration factor rating for stormwater permits
17. NPDES1 – alteration factor rating for major NPDES sites
18. NPDES2 – alteration factor rating for minor NPDES sites
19. Dev_prop – alteration factor rating for developed land uses
20. Agri_prop – alteration factor rating for agricultural land uses

Step 14 – Make a query using the products of steps 10, 12, and 13. Join the ID fields from 10 and 12, and join the CHPP_habit fields from all three tables/queries in the query builder (MS Access or equivalent). Then do the following calculation in a new field:

- ExtPorRat (extent x portion x rating) = ([Drained from Step 10] x [Portion from Step 12] x [Drained from Step 13]) + ([Dredged from Step 10] x [Portion from Step 12] x [Drained from Step 13]) + … + ([Agri_prop from Step 10] x [Portion from Step 12] x [Agri_prop from Step 13])

Step 15 – Make another query to sum the ExtPorRat for each hexagon ID. This is your final alteration score for each hexagon. Export the product of this query to a new table. Join this table to the hexagon coverage to display the distribution of alteration scores. Also fill in the cost field of the Pudata.dat file with the summed ExtPorRat.

PUCVTABLE.DAT

The PuCVTable.dat is used by MARXAN to get the amount of each natural resource target (NRT) in each hexagon. Basically, there is a column for each NRT and a row for each hexagon. A sample table is presented below. Note: pu = planning unit = hexagon ID

pu	1	2	3	4	5	6	7	8	9	10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	5.49	0.00	0.00	0.00	0.00	0.91	0.00	0.00
6	0.00	0.00	15.47	4.94	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	1.52	1.29	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.82	31.52	4.55	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	9.47	6.84	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	3.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	1.37	40.76	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	1.92	10.89	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	7.45	44.52	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	4.73	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00

This file is created from combining the hexagon coverage with the r1_nrt_polygons and r1_nrt_lines coverages. The polygon and line coverages are overlaid separately on the hexagons. The resulting coverages are exported to a database where they are appended to form one table with the following fields.

1. ID - unique identifier for individual hexagons on modeling grid
2. Nrt_type – appended to include the ‘edge’ field from r1_nrt_lines.
3. Nrt_ID – create and populate this field with numbers that correspond to the spec.dat file. Alternatively, you may create the spec.dat file from this file to ensure the identifiers match.
4. Acres – area of NRT in hexagon ID.

Now create a crosstab query to make the PuCVTable. ID field is the ‘row’ field of the crosstab; Nrt_ID is the ‘column’ field; and Acres is the summed ‘value’ field.

BOUND.DAT

The bound.dat file is used by MARXAN to represent the connectivity of hexagons across the landscape. This file is very large and should be created by a utility program. Consult the MARXAN manual for more information.

APPENDIX C: NWI CLASSIFICATION SYSTEM

The following figures were copied from Cowardin et al. (1979)…

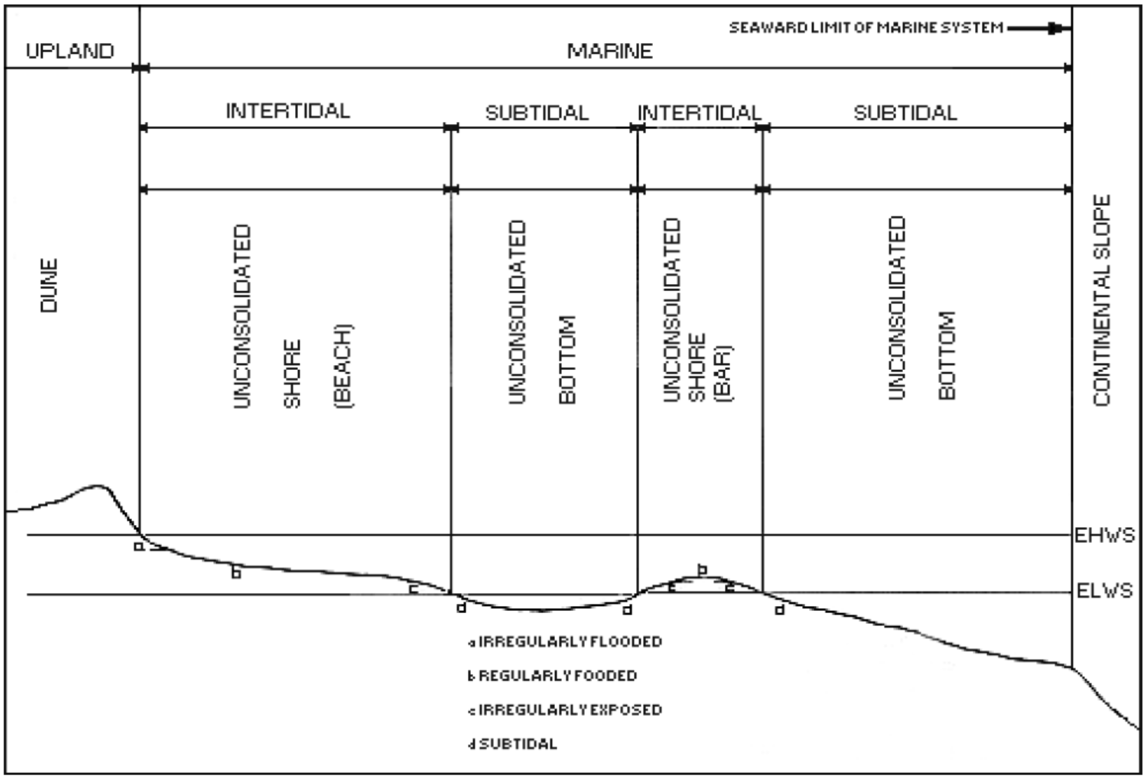

Fig. 2. Distinguishing features and examples of habitats in the Marine System. EHWS = extreme high water of spring tides; ELWS = extreme low water of spring tides.

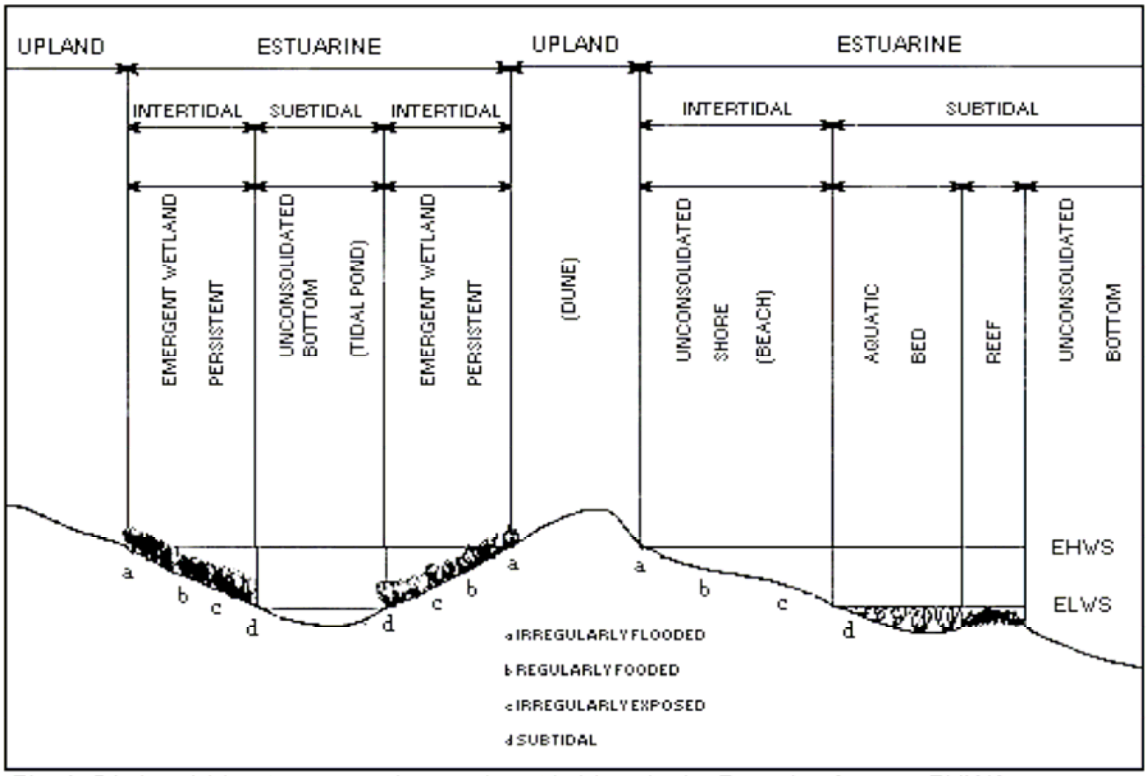

Fig. 3. Distinguishing features and examples of habitats in the Estuarine System. EHWS = extreme high water of spring tides; ELWS = extreme low water of spring tides.

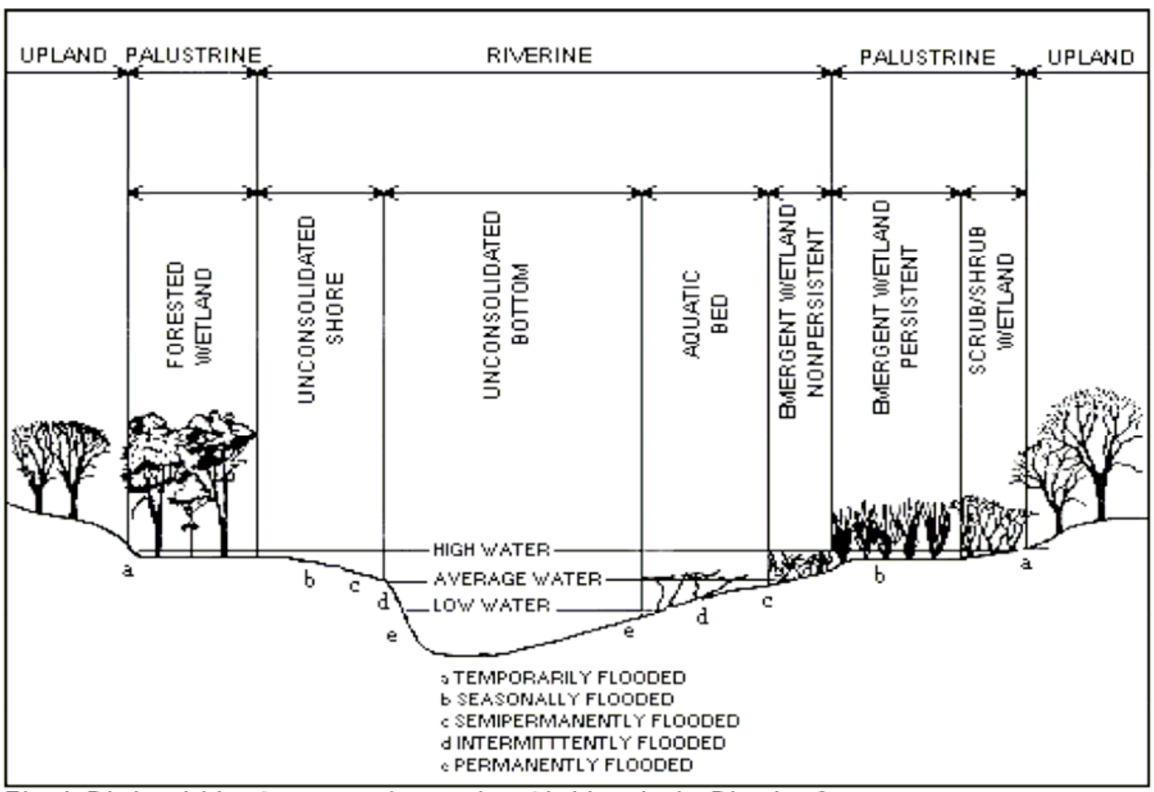

Fig. 4. Distinguishing features and examples of habitats in the Riverine System.

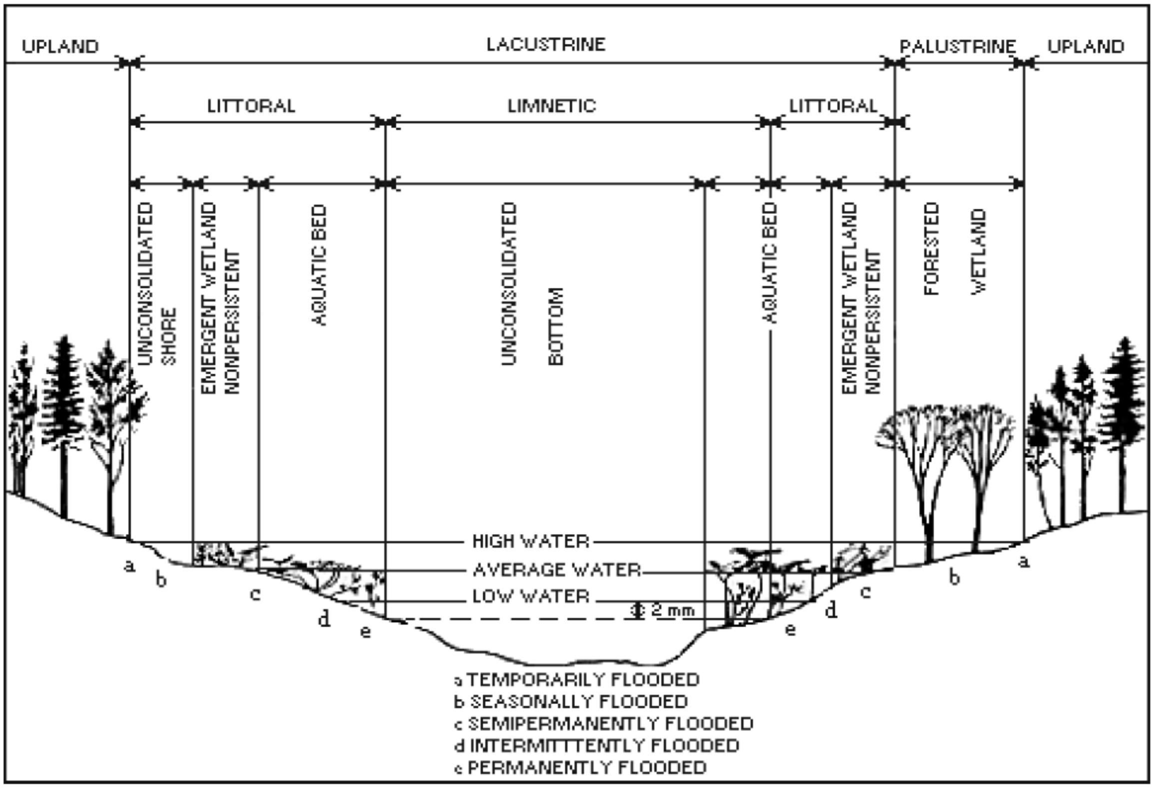

Fig. 5. Distinguishing features and examples of habitats in the Lacustrine System.

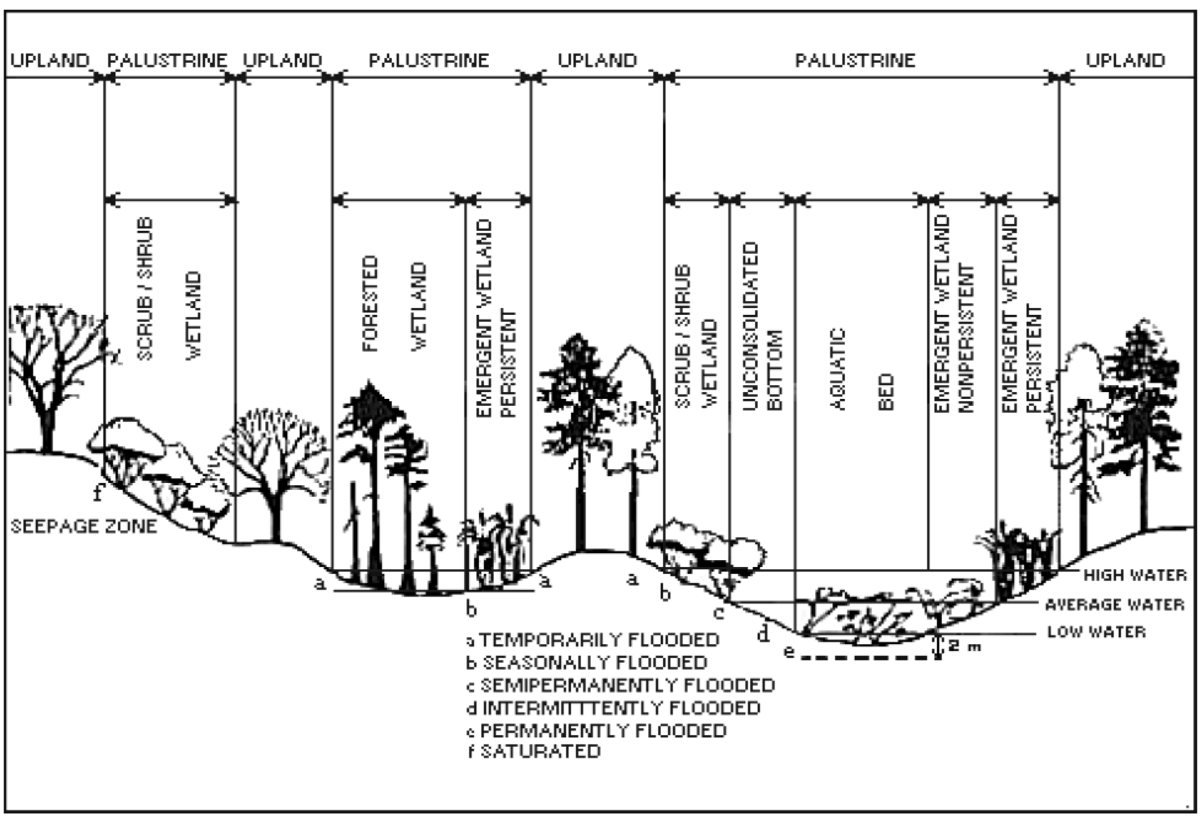

Fig. 6. Distinguishing features and examples of habitats in the Palustrine System.

APPENDIX D: CALCULATING TOTAL ALTERATION

Calculation of the alteration weight for a specific natural resource target within each hexagon takes into account:

1) **S**everity of an alteration factor/threat to each overlapping natural resource target (**S** rating)
2) **E**xtent that an alteration factor/threat overlaps with 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 (= alteration) listed in the threats table of the CHPP (Street et al. 2005, p. 486) (approved by the MFC, CRC, EMC, and DENR in 2004). This rating estimates the potential impact of each alteration factor relative to one another for each habitat type. For water-based factors, such as trawling or dredging, the rating in the CHPP (Street et al. 2005, p. 486) was directly applied. For land-based alteration factors (i.e. land use/land cover), an adjusted S rating is applied to all target hexagons (and portions of hexagons) within their corresponding hydrologic unit (HU). This adjusted S rating is based on the CHPP threats table (Street et al. 2005, p. 486) with an adjustment made for intensity of alteration. The intensity of alteration is determined by scaling the percent coverage in land use category x to a fraction from 0 to 1, which requires knowing the range of percent coverage for land use category x in the analysis region. Once known, a fraction (intensity of alteration) is assigned to the land use coverage within each HU, where the maximum value becomes 1.0 (In Table B-1 below, 50 is scaled to 1 and the lower values scaled within that range). The S rating from the CHPP table is then multiplied by the intensity of alteration to get the adjusted S rating for any given hexagon. For example, if the S rating for cropland on SAV is 2, and the hexagon lies within an HU with 40% cropland coverage where the maximum percent cover in the study area is 50 (0.80 intensity of alteration), the resulting S rating for that hexagon would be 2 x 0.80 = 1.60 (Table B-1).

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

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

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

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

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

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

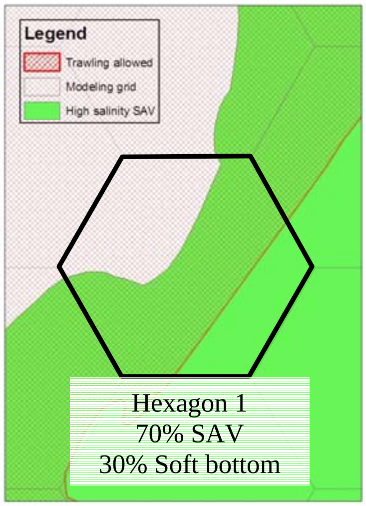

Figure B-1. Calculation of E rating for hexagon-based (water-based) alteration factors. Trawling (e.g. trawling, dredging).

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

Hexagon#	**Natural Resource Target**	**Total area (acres)**	$S_{trawling}$	$E_{trawling}$	**P**	**S x E x P**	**Total weight**
Hexagon1	SAV	70	2	0.60	0.70	0.84	1.14
	Soft bottom	30	1	1.00	0.30	0.30	

Where more than one factor occurs 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 where multiple factors and habitats occur.

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

APPENDIX E: PUBLIC MEETING COMMENTS

MEMORANDUM

TO: North Carolina Marine Fisheries Commission (MFC)
MFC Habitat and Water Quality Committee
Louis Daniel

FROM: Anne Deaton

RE: Strategic Habitat Area Public Meeting
October 8, 2008 Edenton, NC 7:00 pm

A public meeting was held on October 8, 2008 in Edenton NC. The purpose of the meeting was to get public input on the draft SHA selections and management actions that should be considered. There were 25 people at the meeting, seven of which were DMF staff. Also present were two SHA Advisory Committee members, a member of the Northeast Advisory Committee, a member of the Habitat and Water Quality Committee, and the CHPP coordinator. Local government, fishermen, and citizens attended. After a presentation by Anne Deaton of the SHA identification process, Scott Chappell went over the known habitat condition within each of the draft SHA nominations. Those in attendance were asked if they felt the draft SHAs seemed appropriate (exceptional or at risk), if there was any additional corroborating information on any of the 20 proposed sites, if they had any additional information on areas that were not selected, and specific actions they would recommend for specific SHA nominations.

Overall the public seemed supportive of the SHA nominations and wanted to see more protection of these areas. They did not have a lot of specific comments on the condition of the individual SHAs. Some had information regarding nutrient levels in several areas, and one person thought the lower Perquimans River up to Goodwin and Mill creeks that was designated as Anadromous Fish Spawning Area should be included. Scott explained that these areas were not selected because of higher alteration levels. This was also true for many areas that were not selected. Someone noted that upland fields were sometimes included in the SHA because of the hexagon size, but should be clipped out.

Comments on habitat conditions:

- They are not seeing the winter die off of SAV like they used to, and felt it was due to warmer winters.
- There was currently a lot of crab pot mortality in the lower half of the Chowan River, but Sara said that was due to high salinity salt wedge.

Suggestions for management recommendations:

- Tighten up land use plans and enforce them. Need more participation from resource managers in planning process; currently very low attendance at public meetings.
- Address development most because that is what has changed in this area.
- Larger buffers. The 50' buffer for forestry land clearing is too narrow – destabilizes trees and they fall over.
- Resolve misunderstanding between Soil and Water Districts and DWQ regarding use of flashboard risers to restore hydrology.
- Establish impact fees to buy land adjacent to SHAs. However, it was discussed that this conflicts with the northeastern counties need to grow for financial reasons.
- Improve educational outreach on needed management actions (Noted misinformation of stormwater rules turned local government against what was a good thing).