PROCESS FOR IDENTIFICATION OF STRATEGIC HABITAT AREAS IN COASTAL NORTH CAROLINA

by
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With guidance from the North Carolina Marine Fisheries Commission's
Strategic Habitat Area Advisory Committee

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INTRODUCTION

In 1997 the North Carolina Fisheries Reform Act was signed into law, mandating preparation of a Coastal Habitat Protection Plan (CHPP) by the Department of Environment and Natural Resources (DENR) (G. S. 143B-279.8). The legislative goal for the CHPP is long-term enhancement of the coastal fisheries associated with coastal habitats. The plan provides a framework for management actions to protect and restore habitats critical to North Carolina's coastal fishery resources. The CHPP (Street et al. 2005) was approved in December 2004 by the three primary regulatory commissions that have authority over activities that affect coastal fish habitat and water quality – Marine Fisheries Commission (MFC), Coastal Resources Commission (CRC), and Environmental Management Commission (EMC). Implementation plans for each commission, their administrative divisions, and the Department were approved in June and July 2005. Under the Act, actions taken by all three commissions pertaining to the coastal area, including rule making, are to comply "to the maximum extent practicable" with the approved CHPP. The CHPP helps to ensure consistent actions among the commissions, as well as support from other DENR agencies.

Strategic Habitat Areas – definition and concept

Goal two of the CHPP is to "Identify, designate, and protect Strategic Habitat Areas" (SHAs). **SHAs are defined as "*specific locations of individual fish habitats 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.*"** The SHA concept is somewhat similar to MFC designation of Primary Nursery Areas, although Strategic Habitat Areas may be selected using a combination of habitat characteristics and other criteria, such as ecological functions for fish, fish abundance or vulnerability. Thus SHAs, by definition, are a subset of all coastal fish habitat.

Purpose of SHA Committee

The Marine Fisheries Commission established the Strategic Habitat Area Scientific Advisory Committee to assist DMF and other DENR staff in developing the process for SHA identification and designation. The SHA committee consists of 12 scientists and environmental professionals with a wide scope of expertise in fisheries and coastal habitats. The committee began meeting in August 2005. **The goal of the SHA Committee is to recommend a scientifically based process and criteria to identify Strategic Habitat Areas throughout coastal North Carolina.** The MFC is responsible for the official designation of the specific areas, using the methods recommended by the committee. Areas selected as SHAs will be given additional site-specific measures of protection, as necessary, to maintain or enhance their ecological condition. The need for regulatory and non-regulatory protective measures will be determined by a separate SHA Management Committee and were not a function of the current SHA Committee. The SHA Management Committee[1] will consist of experts from Division of Marine Fisheries (DMF), Division of Coastal Management (DCM), and Division of Water Quality (DWQ) and other environmental agencies as determined by the Fisheries Director (Director of DMF) and MFC.

Comprehensive habitat designation structure

There are several existing habitat-related designations included in the MFC rulebook (e.g., Primary Nursery Areas [PNAs], Crab Spawning Sanctuaries, Shellfish Producing Habitat, No Trawl Areas, etc.) (MFC 2005). These past designations were usually based on protecting a certain fishery

[1] The existing CHPP Team, including staff from DMF, DCM, DWQ, Division of Environmental Health (DEH), and Wildlife Resources Commission (WRC) expanded to include some additional agencies, was suggested to serve as the SHA Management Committee.

function (e.g., PNAs – nursery function, determined by juvenile fish data), or protecting a specific habitat from certain fishing gear impacts (e.g., No Trawl Areas in submerged aquatic vegetation). Designation of PNAs represents a successful example of ecosystem management, since it protects the nursery function of multiple shallow habitats from trawling and navigational dredging impacts and resulted in higher water quality standards as the CRC and EMC enacted rules under their authorities to manage coastal development and water quality.

The location of SHAs will be based on the spatial occurrence of multiple habitats, important ecological functions provided by an area, and the influence of water- and land-based threats. The SHA designation differs from previous designations in that areas may be selected that provide either exceptional value for any number of important fish functions, or that are particularly at risk due to an imminent threat, or vulnerability, or rarity. Furthermore, while the existing designations, with the exception of PNAs, focus primarily on fishing gear related actions, areas designated as SHA will require various site-specific regulatory and/or non-regulatory management actions that best address the threats affecting that site.

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. The DMF plans to recommend that the MFC reorganize and modify their habitat definitions and associated rules to reflect a comprehensive habitat classification/protection approach that includes SHAs as one of several tools to protect, enhance and restore fish habitat. A reorganized habitat classification system might include the following categories:

X. Fish Habitat Areas

- X1. Anadromous Fish Spawning Areas - MFC designation and rules pending
- X2. Anadromous Fish Nursery Areas – not currently designated in rule
- X3. Submerged Aquatic Vegetation– not currently designated in rule
- X4. Shellfish Producing Habitat – not currently designated in rule
- X5. Crab Spawning Sanctuaries - MFC rules already in place
- X6. Primary Nursery Areas - MFC, EMC, CRC rules already in place
- X7. Strategic Habitat Areas – MFC, CRC, and EMC rules to be established - may include habitat complexes consisting of any combination of the above, as well as other habitats.

BACKGROUND - METHODOLOGY USED IN SIMILAR ECOLOGICAL ASSESSMENTS

Habitat designations in North Carolina have been based on geographically referenced fish abundance data (e.g. MFC designation of PNAs) and on scientific documentation of habitat value (e.g. federal regional fishery management council designation of Essential Fish Habitat). Both designation processes involve identifying areas that are important for multiple species. PNA designation is based on catch-per-unit-effort of certain juvenile species in shallow estuarine waters in spring and early summer, as well as other factors such as water depth, bottom type, and fish diversity. It can be considered a model for SHA designation.

In recent years, there has been increasing awareness of the need to manage aquatic resources on an ecosystem scale (Beck et al. 2000; NRC 2001). SHAs will be conceptually similar to Marine Protected Areas (MPA) and Marine Managed Areas (MMA). Both attempt to identify exceptional habitat areas by conducting regional ecological assessments. Likewise, both attempt to protect designated areas by managing a broad suite of activities that could negatively affect their quality. Management of MPAs has traditionally focused on increased protection against water-based impacts such as the effect of fishing on benthic habitats, the effects of fishing on fish populations, and the effects of boating activity (anchoring, no motor zones). However, some Marine Managed Areas have focused on land-based threats, as well.

For fishery management purposes, MPA identification usually involves assessing habitat condition using biological integrity indices or other measures, and assessing site-specific productivity (Hartwell 1998). Habitat areas that result in relatively high net export of organisms, such as spawning or nursery areas, are considered strategic areas to protect due to their contribution to fishery stocks. Scientific evidence supports the concept that local fish population density can be a meaningful indicator of habitat value (Kramer et al. 1997). However, this information requires extensive sampling, and is species specific and highly variable. To overcome fish data limitations, many MPAs have used site-selection computer programs, based on **the assumption that the conservation of some representation of all habitats will conserve a representation of the diversity of species and ecological functions found within the overall ecosystem** (Noss 1987; Ward et al.1999). The designated amount of habitat needed for conservation has ranged from 10 to 70 percent, depending on the ecological goals and the particular vulnerability and threats to the system; 20-30 percent is generally considered an adequate conservation target (NRC 2001).

MARXAN and SITES are two site-selection programs that have been used with terrestrial and marine systems. MARXAN and SITES are similar programs that use 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). A Duke University master's project investigated possible methodology for SHA identification in North Carolina and recommended use of MARXAN (Smith 2005). Consequently, the SHA committee considered use of MARXAN as a possible tool when beginning discussions of the identification process and decided to pursue use of the program with modifications. 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. The SHA committee 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.

Site-selection programs use three basic layers of information – a geospatial layer of the natural resource targets (habitat map), an alteration layer that depicts the location of threats or alteration factors (threat map), and a hexagonal modeling grid that divides the project area into a series of standardized units for analysis. 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. 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 selection is ultimately based on other factors as well, and incorporates expert scientific knowledge to help overcome information gaps and consider socio-economic factors that may not have been included in the computer program. Thus, the site-selection program is a decision-support tool.

Ecoregional assessments have been conducted in 45 of 81 ecoregions of the United States (Beck et al. 2000) by nonprofit organizations such as The Nature Conservancy (TNC), marine research institutes such as Scripps Institute of Oceanography, federal agencies such as NOAA, and state agencies such as the Washington Department of Fish and Wildlife. Some assessments were limited to marine waters and conducted with the primary goal of selecting Marine Protected Areas, which in turn led to the implementation of fishery regulations (Lewis et al. 2003). In the Northeast and Mid-Atlantic areas, a marine assessment was conducted to identify Essential Fish Habitat for multiple fishery species (Cook and Auster 2005). Other applications have included aquatic and terrestrial assessments that served as non-regulatory guides for habitat protection, such as prioritization of land acquisition, conservation easements, and habitat restoration efforts (Floberg et al. 2004). In the latter assessments, land and water conservation priorities were considered simultaneously. Spatial analysis and site-selection programs were used successfully in Australia for zoning marine waters in the Great Barrier Reef Marine Park, and in Washington for focusing and synergizing land and sea conservation and restoration efforts in the Puget Sound region. Scientists (Lewis et al. 2003; Z. Ferdana, TNC, pers. com., 2006) involved in these efforts found that such an approach:

- Enhanced their ability to demonstrate to stakeholders the transparency and objectivity of the process;
- Improved the quality of information included in their analysis;
- Made it possible to rapidly and visually consider multiple scenarios based on different inputs and objectives;
- Enhanced their ability to rapidly produce maps and generate legal boundary descriptions;
- Allowed them to make a smooth transition from the analytical method to the human expertise needed to finalize the selection of conservation areas; and
- Served as a guide for more detailed site planning and implementation.

In the Williamette Valley-Puget Trough-Georgia Basin ecoregional assessment (Washington state), which included upland, freshwater, estuarine, and marine systems, use of a site-selection program successfully resulted in identification of a network of priority areas that were used to guide and direct detailed site planning, and effective implementation efforts (Z. Ferdana, TNC, pers. com. 2006). The assessment results have directed and fueled several shoreline initiatives by various partners, including land acquisition of priority areas and restoration of priority shorelines (www.nature.org.). The Alliance for Puget Sound Shorelines have coordinated an $80 million fund to acquire new parks and natural areas, restore tidal marshes and shellfish beds, revegetate shorelines, and remove shoreline armoring (www.shorelinealliance.org). For example, in southern Puget Sound, submerged lands in Woodard Bay, identified as a priority in the assessment, were leased to TNC to restore a native oyster community (Z. Ferdana, TNC, pers. com. 2006). In addition, efforts are underway to protect additional shorelines through strengthening of key policies that address issues such as shoreline hardening, reducing threats from invasive species, maintaining vegetated buffers along currently undeveloped shorelines, and reducing pollution from point discharges.

The SHA committee partly incorporated the same general steps used in these past successful efforts to develop a scientifically sound method for establishing SHAs in a manner that is appropriate for the overall goal of the CHPP – long-term enhancement of coastal fisheries through enhancement of coastal habitat. Terminology was modified to better suit this specific application of the tool to North Carolina. The spatial precision or specificity in the natural resource targets may be critical to produce an adequate representation of habitat and biodiversity. The SHA process differs somewhat from past assessments in that its goal is to select areas that are high quality **and** other areas that are "at risk" from land and water-based threats. In contrast, most primarily terrestrial assessments have focused on selecting only the highest quality areas so that conservation efforts can be focused on sites with the least alteration.

With many marine assessments, there are often large information gaps regarding the condition of the habitat; thus, assessments tend to select high priority areas of certain condition that, if effectively managed, would protect a representative subset of marine biodiversity in an ecoregion. (Refer to Appendix A for a list of additional information on previous applications of MARXAN and SITES.)

STRATEGIC HABITAT AREA EVALUATION PROCESS – NORTH CAROLINA

The SHA committee agreed on the following basic premises regarding the SHA process:

- The process should be transparent, repeatable, and scientifically defensible.
- To begin identification of SHAs, the process must define the natural resource targets for protection, enhancement, or restoration.
- The process can be driven by concerns for either a fish habitat or fish complex (more than one species that share similar life history traits and are often targeted collectively in one fishery – e.g., anadromous fish complex or reef fish complex).
- Selection of SHAs should be flexible and adaptive to allow for addition or modification of SHAs, if necessary.
- Public input should be an integral component in the selection process.
- The final boundaries should take into account enforceability as a practical matter.

The SHA committee was aware that any designation process where undesignated areas receive less protection, results by default, in those areas being more susceptible to future alteration. When one area is given a higher level of protection than another, development is displaced toward the undesignated areas. Therefore the proportion of prioritized ecological areas (SHAs) is important to the overall effectiveness of the designation. However, the SHA process allows for a tier of protection for areas that merit special attention, such as the depleted stock status of fishery species, the imminence of a particular threat, or the relative rarity of the habitat. The nature and continuity of threats will determine if some altered habitats are strategic candidates for enhancement or restoration. Because of biological, ecological, political, and anthropogenic factors, some habitats are more strategic than others. While not all habitats can be given the same level of protection, those that are particularly important and especially needing protection should be the subject of additional regulatory protection. This approach does not mean undesignated areas are not necessary to healthy coastal fisheries. It simply reflects a realistic conclusion that coastal waters support many economic interests that compete with the protection and management of marine and estuarine fishery species[2].

Because selected SHAs can consist of a gradient of ecological conditions, from “exceptional” to “particularly at risk,” different management strategies may be applied to sites with different ecological conditions. While protection refers to maintaining the existing amount and quality of a habitat, enhancement involves improving the quality and function of an existing habitat, and restoration involves increasing the amount and function of an existing habitat by returning a destroyed or extensively altered area to its former condition. The US Army Corps of Engineers, for wetland compensatory mitigation purposes, defines protection, enhancement and restoration as the following (USACE 2002):

[2] Given these many constraints, the SHA committee cannot evaluate how the outcome of the designation process will affect fisheries in the future. Improvements will require changes in the overall, long-term management of watersheds, estuaries, and marine resources that have become degraded over decade to century timeframes of human activities. Improvements, likewise, will require long-term efforts to reverse past (and ongoing) negative impacts. An evaluation of the likelihood that society will provide resources to implement improvements is beyond the charge of this committee.

“Protection (Preservation)–The removal of a threat to, or preventing the decline of, wetland conditions by an action in or near a wetland. This term includes the purchase of land or easements, repairing water control structures or fences, or structural protection such as repairing a barrier island.

“Enhancement – The manipulation of the physical, chemical, or biological characteristics of a wetland (undisturbed or degraded) site to heighten, intensify, or improve specific function(s) or to change the growth stage or composition of the vegetation present. Enhancement is undertaken for specified purposes such as water quality improvement, flood water retention, or wildlife habitat.

“Restoration – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural or historic functions to a former or degraded wetland. Restoration is classified as re-establishment or rehabilitation. Re-establishment results in rebuilding of a former wetland, while rehabilitation results in a gain in wetland function but not acres.”

SHA Process

After a year of meetings, the SHA advisory committee recommended the following steps for SHA identification and designation. Figure 1 provides a schematic of the general process.

Data preparation

1. The DMF determines the geographic area of focus based on fishery or habitat concerns of the MFC, using Figure 1, Step 1.

2. Preliminary input is gathered from appropriate scientific experts and resource managers on (1) potentially important areas within the geographic area of focus for SHA consideration, (2) specific recommendations regarding data to include in analyses, and (3) weightings to apply to natural resource targets and alteration factors. This would be done at a SHA scientific data workshop to which a panel of regional expert would be invited. A presentation explaining the technique to be used would be needed.

3. Potential criteria (including natural resource targets and alteration factors) identified by the SHA regional expert panel or workshop attendees are selected and compiled in geospatial format and initial target representation levels and alteration factor weightings are determined and justified.

Ecological Evaluation

4. DMF staff conducts preliminary ecological assessment of the natural resource targets using the SHA template (Figure 1, Step 2) and a GIS database to assess and corroborate site selection (refer to report for further specifics). MARXAN or other equivalent scientific site selection methods (e.g. VISTA, Arcview ModelBuilder, or customized mathematical routine) that assign quantitative value to natural resource targets and alteration factors are used and documented. Several outputs using various specifications should be compiled for review and discussion.

5. **DMF staff and regional expert panels use “computer selected” areas as a starting point and first approximation**. Final identification as a SHA takes into account information gaps and limitations of the preliminary assessment. The preliminary results are reviewed and corroborated with existing habitat condition, supporting fish data, existing ecological designations, known occurrences of rare species or additional local information not captured in the computer output. Remaining gaps will be filled by using professional knowledge provided by expert scientific review, and considering socio-economic factors. Results are modified as needed and possibly

extended to areas without fish data. However, exceptional habitat condition by itself is sufficient to support designation.[3]

6. A post-analysis workshop is held to discuss the expert-modified areas, identify data gaps and needs and make quantitative and qualitative refinements to the areas identified as SHAs based on best professional knowledge and socio-economic factors. This second workshop includes the same scientists as the first workshop, but may include additional people with special information to contribute, such as fishermen, foresters, farmers, agricultural extension agents, local government representatives or other knowledgeable persons.

<u>Nomination and Designation</u>

7. A written report is completed for each SHA analysis, documenting the natural resource targets and alteration factors used, and the justification for the representation levels, factor weightings, and modifications to the "computer selected" SHAs. (Appendix B represents an example report for a test case analysis using the Bogue-Core Sound region.)

8. The report is made available for review by the public, MFC and other scientists with experience in assessment techniques, specific habitats, estuarine processes, fish functional groups and other relevant expertise. The report specifies whether areas were selected for protection, enhancement or restoration, or some combination of those intentions.

9. Public input is received on (a) proposed designations and (b) potential regulatory and non-regulatory management actions needed for the selected SHAs (specific protection, enhancement or restoration). The CHPP Steering Committee (existing committee consisting of two commissioners each from the EMC, CRC and MFC) provides information to their commissions to inform them of the process and to gain support for the designations.

10. The DMF staff makes changes in designations based on the scientific workshop and public meetings, and final SHA areas are delineated within coastal regions and recommended for designation by MFC or WRC.

11. Final public comment on the designations is received.

12. The MFC and WRC designate SHAs in rule with commitment to work toward Department-wide implementation of needed rules and enforcement of applicable rules.

<u>Implementation</u>

13. Management actions needed for proposed SHAs are determined by the SHA Management Committee and approved by the CHPP Steering Committee. The SHA Management Committee (to be established by MFC and Fisheries Director) includes two representatives from the SHA Committee to ensure that the scientific intent of the designation is met.

14. The designated SHAs are re-evaluated periodically to determine condition and modify management strategies accordingly. (If a site has deteriorated from "exceptional" to "at risk," management strategy shifts from primarily protection to include restoration.)

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[3] Since fish sampling design was not created for the purpose of evaluating habitat quality, but to estimate viability of a particular species population, all habitat areas are not sampled and the information collected may not adequately evaluate the quality of habitats. Where data exist however, they can be used to corroborate the quality of an area.

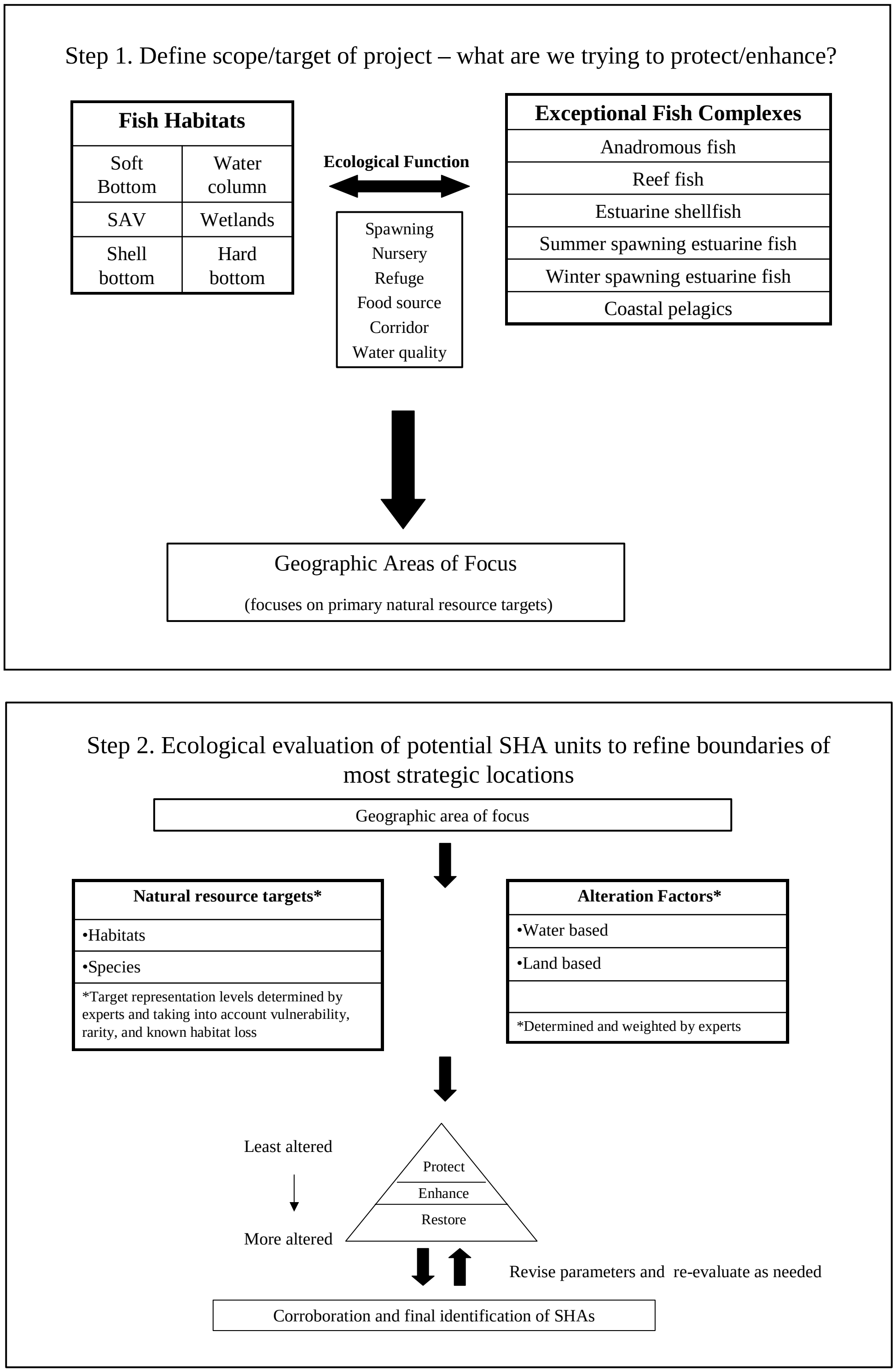

Figure 1. Template for SHA identification process.

Figure 1 shows a general template for use in determining the geographic area of focus, as well as a guide for ecological evaluation of potential SHAs. The process begins by focusing on a geographic area where there is a fishery or habitat-based problem. Analysis considers the co-occurrence of the habitats, fisheries and essential ecological functions of an area, thus suggesting natural resource targets and alteration factors to use for SHA determination.

As an example of the process, the river herring fishery and several other anadromous fishery species (sturgeon, American shad) have been declining over the past several decades, despite fishery management efforts. Species in this fishery are relatively sensitive to water quality and habitat changes (DMF 2006). The SHA analysis would focus on the Albemarle Sound region, where the fishery is concentrated, and would target upstream riverine wetlands and the water column, which are used by anadromous fish species for spawning and nursery functions. Factors contributing to their degraded condition (e.g., physical obstructions, stream channelization, NPDES discharges, and stormwater runoff) would be considered. Potential river herring SHAs should ideally encompass the entire life cycle of the species, including migration routes to offshore wintering grounds. The final boundaries and condition of the SHA unit would be reevaluated and modified as needed.

Determining ecological condition

The functional value of an area, as well as the alteration level, determines its ecological condition (exceptional → at risk → degraded or low habitat function value) (Table 1). Functional value is determined by the occurrence and spatial distribution of natural resource targets, as well as their rarity and vulnerability. A habitat can be considered vulnerable due to narrow tolerance limits of environmental conditions, marginal location within the range for a given species, sensitivity to disturbance or the presence of multiple stressors, or cumulative effects. A habitat can be considered rare due to limited spatial extent, use by endangered/threatened species, or isolation and spatial fragmentation. Vulnerability, rarity and relative degree of loss can be taken into account by customizing the targets and target representation levels in the optimization computation (the portion of habitat to protect) or during the final corroboration and identification process. Other risk factors can similarly be addressed when setting the target representation levels. Ocean hard bottom north of Cape Hatteras is an example of a rare habitat that could be given a relatively high representation level. Because SAV is quite vulnerable to physical and water quality alterations, it could be given a relatively high representation level. To assess ecological condition, DMF staff would compile a GIS database including the appropriate layers of natural resource targets and alteration factors and run the site-selection program (Step 3 and 4 in process).

Continuing occurrence of natural resource targets is an indication that a baseline functioning system exists, with the assumption that the presence of the habitat (targets) will allow continuation of the ecological functions they provide. Low diversity, abundance, and/or high alteration of targets in an area indicates that it currently supports relatively less habitat function than other areas, and might not be selected as a SHA. Those areas with greater habitat diversity (multiple targets present), connectivity among habitats (occurring in close proximity), or rarity may be considered to be providing greater ecological function to a system and could be selected as a SHA. Whereas diversity and rarity are captured by a typical run of MARXAN, connectivity among habitat areas can be included using the "clustering" function within the program. Clustering sets a minimum acceptable size and distance allowed among contiguous selected areas. Alternatively, connectivity among SHAs could be accomplished manually (Steps 5 and 6 in process).

The alteration level is determined by the influence of imminent threats and stressors (alteration) on natural resource targets. Imminent threats can be characterized by human population change, land use change, decline in water quality, occurrence of shellfish closures or other factors. The extent of alteration in an area (i.e., alteration level) will affect the areas' condition and determine whether the potential SHA is in exceptional condition, moderately altered and at risk, or too altered to be selected at this time. The diagram below (Table 1) demonstrates how different levels of function and alteration would determine SHA status. The management triangle at the bottom of Figure 1, Step 2 is a reflection of the function vs. alteration matrix in Table 1.

Table 1. Relationship among ecological function, alteration (risk) level, SHA designation and potential management measures needed.

		Risk/Alteration Level**	
		Lower	**Higher**
Ecological function *	**High**	MEASURES TO CONSERVE AND PROTECT SELECT AS “EXCEPTIONAL” SHA	ADDITIONAL MEASURES TO PROTECT AND ENHANCE SELECT AS “AT RISK” SHA
	Low	MAINTAIN, RESTORE – USE EXISTING PROTECTIONS, EVALUATE FOR RESTORATION CURRENTLY NOT SELECTED AS A CANDIDATE SHA	

*   Represented by co-occurrence of relatively unaltered natural resource targets in an area
** Determined by alteration factors

The committee agreed that specific criteria (i.e., natural resource targets and alteration factors) are necessary for ecological evaluation of potential SHAs (Step 3 in process). Potential natural resource targets and alteration factors are listed in Tables 2 and 3, respectively. Natural resource targets are habitats or ecological functions that represent essential or unique components of the larger coastal system, of which some portion are priorities for selection. Categories of natural resource targets are based on those identified in the CHPP (Street et al. 2005). The data source for each natural resource target and alteration factor varies and will be noted in the evaluation documentation. The natural resource targets and alteration factors listed represent only the current possible targets and factors that could be utilized. A subset of these may be used for the regional ecological assessments. Over time, new information may be available that provides better or additional guidance.

For each regional MARXAN analysis, representation levels for each target must be set. Recall that criteria for representation levels include (1) rarity of a target, (2) vulnerability of a target (sensitivity to alterations), and (3) known amount of historic loss or degradation that has occurred to a target. For example, the larger loss of subtidal shell bottom than intertidal shell bottom (Street et al. 2005) could prompt a higher representation level for subtidal shell bottom.

Table 2. List of potential natural resource targets for SHA evaluation and selection. Each target has subtypes to ensure that functionally different areas in a system are captured. C = complete data available, P = partial

Natural Resource Targets **	Supporting data available
SAV	P
Low salinity species	
High salinity species	
Shell bottom	P
Intertidal, low density shell	
Intertidal, high density shell	
Subtidal, low density shell	
Subtidal, high density shell	
Riparian wetlands	C
Riverine forested wetlands	
Freshwater marsh	
Salt/brackish marsh	
Estuarine scrub/shrub	
Estuarine forested wetlands	
Headwater wetlands	
Wetland edge (transition to intertidal/subtidal)	
Soft bottom	C
Freshwater unconsolidated bottom	
Estuarine intertidal sand	
Estuarine intertidal mud	
Estuarine subtidal (sand or mud)	
Ocean intertidal sand	
Ocean subtidal (sand or mud)	
Non-wetland shoreline	
Hard bottom	P
Freshwater consolidated bottom (riffles and rocks)	
Ocean hard bottom high profile (>0.5 m)	
Ocean hard bottom low profile (< 0.5 m)	
Water column	C
Linear water features (streams, creeks, etc)	C

Table 3. Severity weightings of potential alteration factors (based on Table 9.1 in the CHPP). Ratings: 1=minor, 2=moderate, 3=severe, 0=potential or unknown. Water quality weightings vary with water quality data, where lower water quality = higher severity weight

	Severity of factor					
Alteration factors / activities	**Soft bottom**	**SAV**	**Wetlands**	**Shell bottom**	**Linear water features**	**Hard Bottom**
Hydrologic alteration						
Culverts, bridges, and fill (physical blockages)	0	1	2	1	2	0
Dams	1	0	3	0	2	0
Water withdrawal	0	0	1	0	2	0
Channel and inlet dredging	1	2	2	2	1	1
Channelization/ditching/ drainage	0	0	2	1	1	0
Land use alteration/NPS						
Animal operations	1	2	1	1	2	1
Cropland	1	2	2	1	2	1
Forestry	0	1	2	2	2	1
Impervious roadways	1	2	2	2	2	0
On-site wastewater disposal	1	1	0	1	1	0
Urban stormwater runoff (impervious surface)	1	3	1	3	3	1
Land use change	1	2	3	2	2	0
Population change	1	2	3	2	2	0
Urban/suburban construction activities	1	2	3	2	2	0
Physical habitat alteration						
Boating activity	1	1	0	1	1	1
Bottom trawl	1	2	0	2	1	2
Clam trawl (clam kicking)	1	2	0	2	1	0
Long haul seines	1	1	0	1	0	0
Pots (crab)	0	0	0	0	0	1
Rakes, tongs	0	1	0	1	0	0
Toothed dredge (crab and oyster)	1	2	0	2	1	0
Toothless dredge (bay scallop)	1	1	0	1	1	0
Dredge material disposal (on submerged land)	2	2	0	0	0	2
Estuarine shoreline stabilization	2	1	2	2	1	0
Ocean beach nourishment	1	0	0	0	1	2
Ocean shoreline hardening	1	0	0	0	0	1
Fiber optic cables/utility pipelines	0	0	1	0	0	1
Log salvage	1	0	0	0	1	0
Oil and gas exploration/drilling	0	0	0	0	0	0
Phosphate and other minerals	3	0	3	0	3	0
Water quality alteration/point sources						
Aquaculture (incl. Discharges, intro spp.)	0	0	0	1	1	0
Marinas and docks - construction, assoc. NPS	2	2	2	2	2	0

Table 3. Continued…

Alteration factors / activities	Severity of factor [1]					
	Soft bottom	SAV	Wetlands	Shell bottom	Linear water features	Hard Bottom
Permitted domestic wastewater discharges	2	2	0	1	2	0
Permitted industrial wastewater discharges	2	1	0	1	1	0
Waste disposal (landfills, ocean dumping)	0	0	1	0	0	0
Water quality alteration indicators						
Use Support - Shellfish harvest	0-1	0-3	0	0-2	0-2	0
Use support - Aquatic life	0-3	0-3	0	0-3	0-3	0-3
Use support - Water supply	0-3	0-3	0	0-3	0-3	0-3
Sediment toxicity	0-3	0-3	0	0-3	0-3	0-3
Biotic indices (i.e. IBI, BI, EPT)	0-3	0-3	0	0-3	0-3	0-3
Ambient water quality data	0-3	0-3	0	0-3	0-3	0-3

Creation of alteration layer and weighting of alteration factors

To assess ecological condition of the natural resource targets, a map is created to illustrate the presence of each alteration factor as part of a GIS database. For the MARXAN program, a hexagonal grid is overlaid on the project area that makes hexagons the primary summary (spatial) unit for analysis. The alteration layer expresses the overall impact of the alteration factors within each hexagon. A weighting scheme is used for each alteration factor that occurs in a hexagon. Within each hexagon, a weight index is calculated for each alteration factor with each overlapping natural resource target. The weights for each target are summed to derive a weight for an individual alteration factor. The weights of all alteration factors within the hexagon are summed to obtain a total alteration value for that hexagon. The weight of each alteration factor will be unique depending on the potential severity of the alteration factor, the extent the factor overlaps with the natural resource targets, and the amount of natural resource targets present within the hexagon. (For more specific information on the weighting methodology, refer to Appendix B.)

Running the MARXAN program

Once the natural resource targets and alteration layers have been assembled, MARXAN can be run at various target representation levels and alteration severity ratings to find the optimum configuration of selected areas. A MARXAN run starts with a random selection of target cells that expands via an iterative improvement process that attempts to minimize the total alteration level of the selected area while meeting the representation level for each target, all within the smallest area. A MARXAN analysis generally consists of numerous runs to improve the final selection of areas. Each selected hexagon has an associated selection score that indicates the frequency it was selected (maximum of 100 if run 100 times). To ensure less scattering of selected points—i.e., to ensure that areas are "clustered" into manageable units—a Boundary Length Modifier (BLM) should be applied to the analysis. This variable slightly aggregates the selected units to "smooth" boundaries. This helps to ensure that the areas selected for SHA designation are of adequate size so that management measures can be effectively implemented and enforced. Clustering could also be employed to address habitat fragmentation. Multiple runs should be conducted with a range of representation levels, boundary length modifiers, and weightings to create a variety of scenario outputs for comparison and discussion. After the process is completed, the selection score, alteration level, and source of alteration for the selected areas can be analyzed. In most cases, areas that are selected fewer times are those that are more highly altered. This information can be used to determine SHA type (exceptional or at risk) and subsequent management strategies.

Corroboration and identification of SHAs

Once MARXAN has been run for the selected targets and factors, draft maps will be produced and reviewed. Target representation levels and alteration factor weighting determine which areas are initially selected by the program. DMF staff and the SHA regional expert panel should verify the GIS coverages representing the natural resource targets through review of aerial photos, data and other pertinent information. The regional expert panel may choose to modify the targets, target representation levels or alteration factors, and re-run the program.

Once satisfied with the analytical results, draft SHAs can be selected and modified as necessary. Biological data or other ecological designations (PNA, ORW, HQW, SNHA) are overlaid on the proposed areas as a part of the corroboration and identification process (Table 4, Steps 5 and 6 in process). Fish data must be incorporated into the process with caution because (1) sampling for fish is 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). To proceed toward the final identification:

1) Selected hexagons are clumped into manageable polygons
2) The least altered selected polygons are assessed by considering
    i. Presence of natural resource targets, their rarity, vulnerability
    ii. Existing fish data
    iii. Existing ecological designations (including shellfish leases)
    iv. An area's existing level of protection
    v. Other information from local experts about the targets or alterations not captured in the computer analysis.
3) The more altered selected areas are assessed in the same way.
4) Unselected areas are reviewed to determine if there might be any justification to add them manually. Modifications to the SHAs may be made based on input from the regional expert panel using other known biological or ecological data (same type of information as listed in #2 above). Refinements to the proposed SHAs can be made based on conflicts with known biological or ecological data (i.e. SHA area questioned if biological data indicate little or no productivity).
5) Proposed SHAs will be classified as "exceptional" or "at risk" for management consideration in subsequent stages of the process (Table 1).

Final identification is dependent on both the availability of geospatial data, as well as regional knowledge of the scientific and resource management community. Scientific workshops are essential operational steps of the SHA identification process. Since areas may be added or deleted at various stages in the process, the final percent of selected targets may differ from the desired representation levels initially indicated.

Table 4. Potential types of biological/ecological data for use in validating selected SHAs.

Data type	Data source/availability*
Ecological / Functional Designations	
Anadromous fish spawning areas	MFC rule definition
Anadromous fish nursery areas	MFC rule definition
Estuarine fish nursery areas - PNAs	MFC rule definition and designation
Freshwater nursery areas - Inland PNAs	WRC designation
Blue crab-spawning areas - Crab Spawning Sanctuaries	MFC designation
Designated Significant Natural Heritage Areas	Natural Heritage Program designation
Special water quality designations (ORW, etc.)	EMC rule definition and designation
Species / Productivity Data	
Natural Heritage Element Occurrence	Natural Heritage Program data
Blue crab-nursery	Prg 120, 510, 195
Bay scallop	Prg 635, 697
Clams	Prg. 635, 640 (1 yr in Core Sound)
Oysters	Prg 635, 610; old DMF shellfish maps, and Gene Balance's historical shellfish bed maps
Red drum-spawning	Joe Luczkovich's auditory spawning survey, Prg 310, 360
Red drum-nursery	Prg 120, 123
River herring-spawning	Prg 150, 160
River herring-nursery	Prg 100
Southern flounder-nursery	Prg 120, 100, 195, 915
Shrimp-nursery	Prg 120, 510, 195
Sturgeon-spawning	Prg 150, 160, observer program
Sturgeon-nursery	Prg 100, 135, observer program

* Prg = DMF data program number

SHA nomination

The regional expert panel will produce a nomination report that details the entire process and analysis (Step 7 in the process). The report at a minimum includes the following:

1) Title (Nomination of (Specific Waters) for Strategic Habitat Area Designation)
2) Table of Contents
3) Executive Summary
4) Introduction
   a) General SHA background
   b) Define scope of project
   c) Regional expert panel members
5) Methodology

a) Description of selection tool (MARXAN)
b) Natural resource targets and representation levels
c) Alteration factors and weighting justification
d) Site-selection tool results
e) Maps of various scenarios investigated
f) Corroboration with other existing data

6) Corroboration and Identification Process
   a) Compare targets, alteration levels, and professional judgment to refine area selections
7) Proposed SHAs
   a) Description and class (At risk or Exceptional)
   b) Rules- Boundaries defined
8) Recommended management strategy
9) Appendices (data sources, workshop attendees and summary, etc.)

The draft report will be made public and comments solicited at public meeting(s). A final report will be prepared and submitted to MFC or WRC for their consideration.

SHA TEST CASES

Two test analyses were conducted while developing the SHA process. The lower Chowan River analysis was conducted first and provided insights that led the SHA committee to make numerous changes to the process. An analysis of an area including Core and Bogue sounds and tributaries followed the process and methods described in this report. However, the Core-Bogue analysis was completed prior to final revisions to the process, so there are some changes that would be needed if this evaluation were not a test case. (An example of the written justification report based on the Core-Bogue analysis is included in Appendix C.) After completing this test case, the committee agreed that the geographic scale of the analyses should be at the watershed level, and include connections from upstream freshwater areas to the ocean. The committee also suggested that the analyses be conducted in 4-6 subregions of the coast. A proposed map with four geographic areas for SHA analysis is shown below (Figure 2). Within each region, analysis would be stratified to allow custom representation levels in hydrographically separated areas. Stratification and clustering would also enhance connectivity among SHAs. The boundaries are based on USGS 12-digit hydrologic units, DMF trip ticket water bodies, DMF management districts, and CHPP management units. Each subregion consists of 3 – CHPP management units (e.g., Region 1 consists of Chowan, Roanoke, Albemarle and northern portion of Coastal Ocean units; see Street et al. 2005). Problems for particular fisheries or habitats will drive the in which geographically based analyses are conducted.

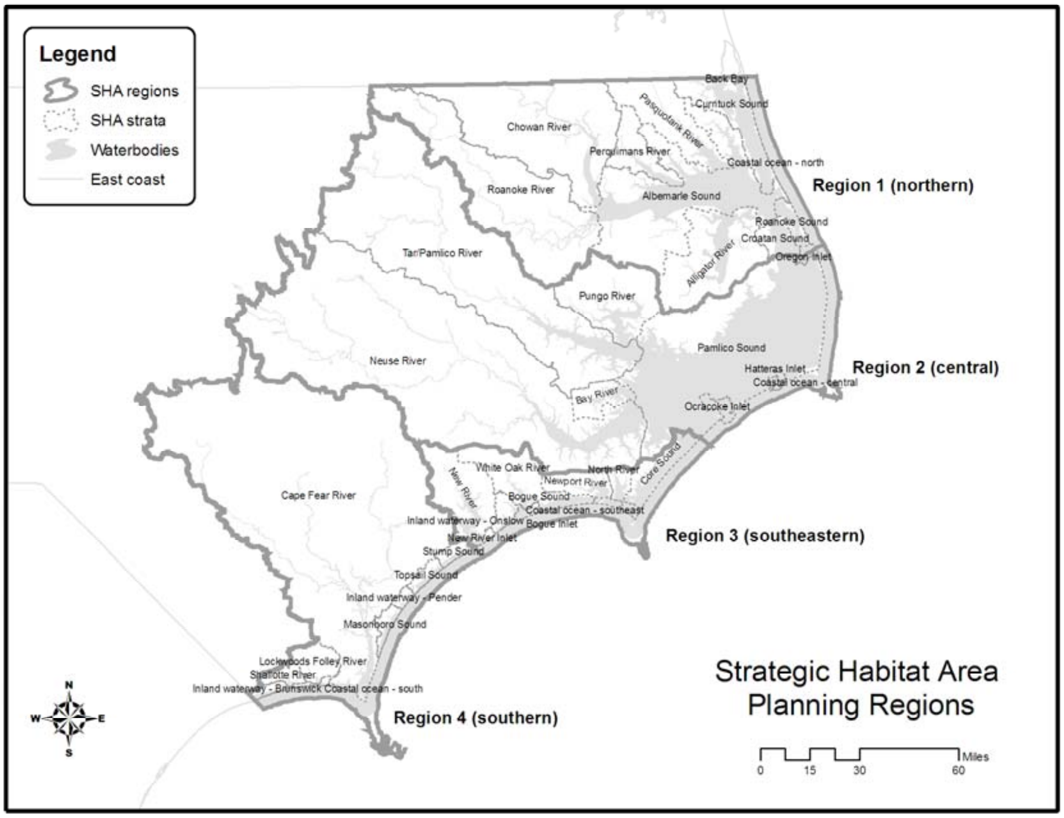

Figure 2. Proposed geographic areas for SHA analyses.

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APPENDIX A: OTHER APPLICATIONS OF SITE SELECTION PROGRAMS

Table A.1 is a list of marine applications of MARXAN/SITES. A brief summary of a few of the more pertinent projects is given below so that the SHA committee can understand past applications of this method, and if it is appropriate for SHA designation in North Carolina. Both MARXAN and SITES were initially developed for reserve design in the Great Barrier Reef Marine Park, Australia and more recently were used for assessments in the South Atlantic, Long Island Sound, Puget Sound and Gulf of Mexico. Both use the same statistical procedure and can be used for aquatic or terrestrial applications. However MARXAN is a more recent user interface that aids in handling files and grouping. MARXAN was used in assessments of the Great Barrier Reef, Australia, and in the South Atlantic, USA, and in the north and mid-Atlantic (Lewis et al. 2003; DeBlieu et al. 2005; Cook and Auster 2005). SITES was used in assessments of the Northern Gulf of Mexico and Williamette Valley-Puget Trough-Georgia Basin ecoregional assessments, (Beck et al. 2000; Floberg et al. 2004; Ferdana 2005).

Table A.1. List of known marine applications of MARXAN/SITES. (http://www.ecology.uq.edu.au/index.html?page=27710&pid=20497).

Location, contacts, and year	Program/Purpose
Florida Keys. Heather Leslie, Postdoctoral Research Fellow, Princeton University	SITES: This was the first marine application of the simulated annealing algorithm, which is part of the SITES/MARXAN packages, all of which were written by Ian Ball in collaboration with Hugh Possingham.
Channel Islands. Satie Airame, Marine Policy Coordinator, University of California, Santa Barbara	SITES: A working group of stakeholders used the siting tool to design a network of fully protected marine reserves for the Channel Islands National Marine Sanctuary.
Australia - Great Barrier Reef Marine Park. Suzanne Slegers, GIS Officer, GBRMPA	MARXAN: This effort will evaluate the existing zoning scheme in the GBRMP to meet biodiversity conservation objectives.
Gulf of California. Enric Sala, Center for Marine Biodiversity & Conservation	SITES: This collaborative effort between marine scientists at Scripps Institution of Oceanography (USA) and World Wildlife Fund yielded possible marine reserve network configurations for the Gulf of California, Mexico.
Willamette Valley-Puget Trough-Georgia Basin (USA/Canada). Zach Ferdana, The Nature Conservancy of Washington	SITES: Conservation planners are using both biological community and species-based conservation targets to draft a network of priority areas for conservation action in the Pacific Northwest (USA).
Galapagos Islands (Ecuador). Rodrigo H. Bustamante, CSIRO Marine Research	MARXAN: The siting tool is being used to further the implementation of the Galapagos Marine Reserve and the associated zoning initiative, and to monitor its performance.
Northwest Atlantic (USA/Canada). Hussein Alidina, Sr. MaHunager WWF Canada; The Conservation Law Found.	MARXAN: Designating areas of high conservation value in the Gulf of Maine/Bay of Fundy/Scotian Shelf/Georges Bank/Offshore waters. It is in the early stages.
New England/Mid-Atlantic Bight. R. Cook, P. Auster, NURC, Univ. of Conn.	MARXAN: Used fish abundance/density data from trawl surveys to determine priority areas for designation as Essential Fish Habitat.

South Australia. Romola Stewart, The Ecology Centre, The University of Queensland	MARXAN: Marine reserve systems are configured to compare solutions that retain South Australia's existing marine reserves with reserve systems that are configured independently.
British Columbia. Jeff Ardron, Living Oceans Society, British Columbia	MARXAN: Staff used the siting tool to explore the possible configurations of a system of MPAs, including fully protected marine reserves, for British Columbia
Connecticut/New York. Amanda E. Wheeler, University of New Haven	MARXAN: MPA designs for Estuary of Long Island Sound - Connecticut/New York. MPA Design Tutorial available in .pdf format (Download), and an abstract describing her work.
South Atlantic. Jeff DeBlieu, The Nature Conservancy, Kill Devil Hills NC	MARXAN: Developed potential set of conservation areas from Virginia to Florida, with focus on marine and estuarine habitats.
Northern Gulf of Mexico. Michael Beck, M. Odaya. The Nature Conservancy, Arlington Va.	SITES: Selected and prioritized conservation areas in estuarine and nearshore ocean from Florida to Texas.

NORTHERN GULF OF MEXICO

This ecoregional assessment is pertinent because many of the habitats, species, and environmental issues are very similar to coastal North Carolina.

Software - SITES
Area – Northern Gulf of Mexico from Florida panhandle through Texas
Scale – Regional, multi-state
Stratification – Subdivided into east, central, west
Conservation targets – Coarse filter: low and high salinity SAV, oysters, hard bottom, tidal fresh and salt marsh, tidal flats. Fine filter: species occurrence if imperiled or declining faster than their habitat
Conservation target goal - 20% for each. Required selected sites to include an entire bay or estuary at a landscape scale – not portions. Used National Wetland Inventory classification. Ranked highest priority sites. Those sites were those needing action for conservation.
Suitability Factors – Did not assess or include in report. The authors discussed in detail the types of threats to the area and noted there were many land-based threats, and the region was highly affected by the hydrology of the system [noted the dead zone off the coast of Louisiana is from agricultural runoff in the Mid-West (huge river basin)].
Noted limitations – Not many imperiled species in area, but that may be due to how species are classified in marine environments versus terrestrial environments.

SOUTH ATLANTIC ECOSYSTEM

This ecoregional assessment is very pertinent because it includes North Carolina. However it focuses primarily on the ocean and is at a larger and coarser scale than we are considering for SHAs.

Software - MARXAN
Area – Virginia to Florida, ocean continental shelf and estuarine waters
Scale – Regional, multi-state. Each hexagon = 1500 ha (3706.6 acres)
Stratification – Subdivided into 6 subregions: east, central, west, each with an inshore and offshore region. Purpose of stratification is to ensure adequate representation and conservation of diversity throughout region.

Conservation targets – Coarse filter: SAV, marsh, coral reef, hard bottom, shoreline type (from NOAA Environmental Sensitivity Index), bottom structure complexity (depth contour as surrogate of habitat diversity and species abundance), and federally designated Habitat Areas of Particular Concern. Fine filter: species occurrence if imperiled or declining faster than their habitat- included shortnose sturgeon, sea turtles, right whale, piping plover, American oystercatcher.
Conservation target goal - 30% or more for each except piping plover (50%), tidal flats (40%).
Suitability Factors – Population change (1990-2000), housing density, road density, ports, shipping lanes, dredged ship channels, hardened shorelines, EPA superfund sites, NPDES sites, dredge material disposal sites
Noted limitations

- Structural complexity not groundtruthed
- Connection between sites subjective

WILLIAMETTE VALLEY-PUGET TROUGH-GEORGIA BASIN (WV-PT-GB)

This ecoregional assessment is pertinent because it includes freshwater, estuarine, marine and terrestrial environments. The area has important anadromous fish populations and many land-based threats that could be similar to North Carolina.

Software - SITES
Area – Oregon, Washington, British Columbia – approx. 21,400 mi^2, > 10,000 mi river and streams,
Scale – 2 states, 2 countries. Area includes ¾ of population in Oregon, Washington, British Columbia. Hexagons were 750 ha (1853.3 acres) each.
Stratification – Subdivided into four regions (north to south) and within each region, conducted freshwater, nearshore ocean, and terrestrial analyses.
Reason for assessment – rapid population growth and land conversion

(WV-PT-GB) Freshwater Assessment

Used watershed drainage units - different than what used in terrestrial and nearshore. Habitat of streams/rivers characterized by stream size, elevation zone, geology, and gradient/land form, with stream size being most important characteristic. This is based on the river continuum concept. The water bodies were classified using a multi-variate analysis to get them into an appropriate spatial format. Model would strive to represent some percent of all of the different stream classifications since each type serves unique ecosystem functions. In our test case model (see next section), we have not done this. Once the model was run, an expert workshop resulted in significant addition of sites that improved targets and connectivity. Confidence of site selections was rated, whether determined by model, expert, or some combination.

Conservation Targets – Coarse filter: waterbody classification types; fine filter: species naturally rare, severely threatened, endemic, or declining in abundance. Included 13 fish, 8 molluscs, 3 other invertebrates, 12 plants.
Suitability Factors – Road density, dam density, land use (% non-natural), point sources (#/km)
Noted limitations:

- Very few targets have enough information available to estimate with confidence the exact percent or amount of habitat needed to ensure long-term survival. Requires subjective selection.
- Freshwater targets lacked species data, except salmonids, so they set target goal at 100% of all the known occurrences to ensure that at least some representation of poorly documented species was included.
- Salmon are keystone species and many are imperiled, but they are excluded in model because of their complex life history (and because of politics). Did take into account somewhat with natural resource targets.

- First approximation. More complete for some species and habitats than others.
- Incomplete/unequal solicitation of experts.

Noted strengths:

- Because the analysis includes numerous targets at numerous locations, evaluation of the biodiversity and suitability is very complex and would be very time-consuming or impossible to assess all the possible scenarios and outcomes without such a model.
- Improves on information available at an ecoregional scale.

(WV-PT-GB) Nearshore Assessment

Stratification – Divided into estuarine and nearshore marine

Conservation Targets- 40 coarse filters, 68 fine filters. Pertinent coarse filters – biophysical shoreline types (similar to DMF bottom mapping strata system - e.g. sand flat with kelp). Fine filters: 9 fish, 3 marine mammals, 11 birds, 10 invertebrates. Data from element occurrences, fishery agency data, spawning sites, trawl survey data, video surveys. Spawning sites were presence/absence data, noting absence may be lack of sampling effort rather than absence of fish (similar to NC's data situation).

Conservation Target Goals – Habitat goals varied between 15 and 50%, felt 30% was good average. Gave higher goal to shoreline types having more vegetation types on them (indicator of diversity). Species goals 30-60%.

Suitability Factors- Shoreline modifications, lands managed for conservation, fishery closures. Because they didn't have exact locations for many rockfish, they used seasonal fish closures (spawning closure?) as a positive factor, indicating their presence.

Noted Limitations:

- Didn't have juvenile fish abundance data, % of historic vegetation, limited invertebrate data. Can't assess equally because information available is unequal.
- Didn't include water quality data

Lessons learned from review of past MARXAN/SITES projects:

- To use the MARXAN model effectively, the evaluation must consider multiple species and habitats.
- SHA evaluation process in North Carolina should probably be stratified regionally (using river basin boundaries and USGS hydrologic units for delineation) to maintain connectivity between selected SHAs.
- If MARXAN is used, scientific workshops for each subregion should be held following initial assessment to evaluate and modify results.
- It is appropriate to manually add sites that are of high fishery importance when deemed necessary. For example, if river herring are declining faster than their habitat, and data are available that documents some portion of the spawning sites, they could be added, regardless of the computer results, and included as SHAs.
- The level of detail included in development of suitability indices varied greatly. Consider the purpose of including the factors.
- None of the reviewed reports included direct water quality information in the analyses, other than NPDES sites and factors that could be indicators of water quality degradation. Including more direct water quality data could be too complicated for the scale of the projects.

APPENDIX B: CALCULATION OF THE ALTERATION FACTOR WEIGHTINGS

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).

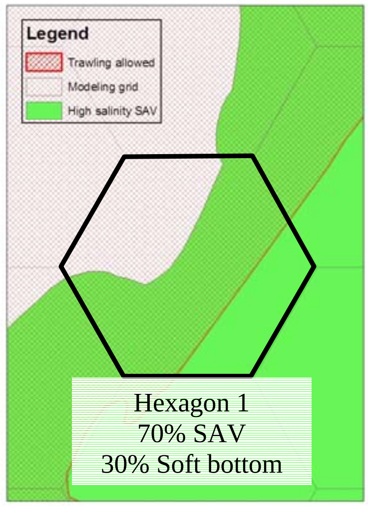


Figure B-1. Calculation of E rating for hexagon-based (water-based) alteration factors. Trawling (e.g. trawling, dredging).

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 C: NOMINATION REPORT FOR TEST CASE REGION

Introduction

The identification and designation of Strategic Habitat Areas (SHAs) 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. For this test case, the SHA Committee served as the regional expert panel (Table C-1). This report focuses mainly on the scientifically based portion of SHA identification in the Core and Bogue sounds area of the central North Carolina coast and follows the nomination report format specified in the SHA report. This work is considered a pilot project demonstrating the application of the process and criteria recommended by the SHA committee. It is not intended as a process to officially nominate any areas for SHA designation.

General SHA background

The designation of SHAs is meant to identify priority aquatic areas for protection, enhancement, and restoration. Once these areas are identified, resource managers would address gaps in existing management of functionally important habitat areas and take steps to prevent further alteration of the system as a whole. Thus, the necessary protections may go above and beyond some current measures designed to protect habitat. Designation of SHAs is meant to address the continuing degradation and loss of important habitats referenced in the CHPP (Street et al. 2005). The SHA committee recommended use of a GIS-based site-selection computer program (MARXAN) as a decision support tool to identify SHAs. MARXAN utilizes available geospatial information on the distribution of habitats and alterations 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 will be required to finalize identifications and nominations of areas for SHA designation.

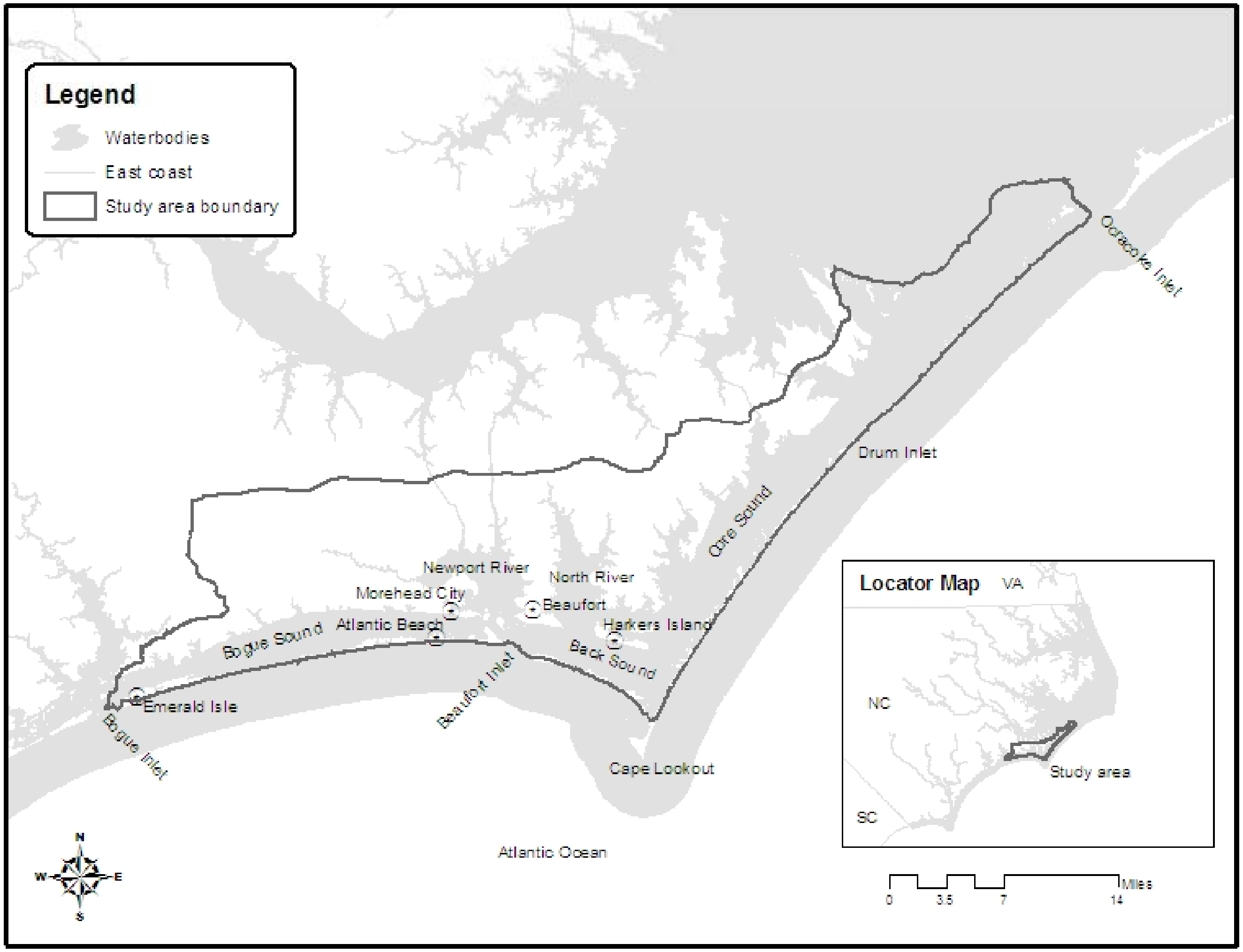
Scope of analysis

A sub-basin of the White Oak River Basin in North Carolina, containing Core and Bogue sounds and their tributaries, was chosen due to concerns for several important and declining fisheries in the areas (e.g., bay scallop, oysters) and the regional expert knowledge represented by the committee members. The boundaries of the study area were based on a combination of USGS 12-digit hydrologic units and the CHPP management unit for Core/Bogue (Street et al. 2005). The study area is located in Carteret County and is bounded on the north and south by Ocracoke and Bogue inlets, respectively (Map C-1). It includes the barrier islands of Core, Shackleford, and Bogue banks, and mainland communities of Morehead City and Beaufort, as well as the unincorporated "down east" communities bordering Core Sound.

Table C-1. Regional expert panel for the Core-Bogue SHA test analysis.

Name	Affiliation	Work location
John Fear	NC Division of Coastal Management	Morehead City, NC
Carolyn Currin	NOAA, National Ocean Service	Beaufort, NC
Trish Murphey	NC Division of Marine Fisheries	Morehead City, NC
Jeff Buckel	NC State University, C-MAST	Morehead City, NC
Troy Alphin	UNC-W, Center for Marine Science	Wilmington, NC
Mark Brinson	ECU, Department of Biology	Greenville, NC
Bennett Wynne	NC Wildlife Resources Commission	Kinston, NC
Tom Lankford	UNC-W, Department of Biology	Wilmington, NC
Hans Paerl	UNC-Chapel Hill Institute of Marine Science	Morehead City, NC
Bill Kirby-Smith	Duke University Marine Laboratory	Beaufort, NC
Steve Murphey	NC Division of Environmental Health, Shellfish Sanitation	Morehead City, NC
Eric Fleek	NC Division of Water Quality, Environmental Sciences Section	Raleigh, NC
Jud Kenworthy	NOAA, National Ocean Service	Beaufort, NC

Map C-1. Map of study area showing extent of natural resource targets and major water features.



Methodology

The regional expert panel for Core/Bogue used the master lists from the SHA report (Tables 2 and 3) to select a subset of relevant natural resource targets and alteration factors. Targets and factors used in this analysis are shown in Tables C-2 and C-3. The data for each target and alteration factor were prepared according to the preparation notes in those tables. For alteration factors, the data preparation was determined by the metric used from Table C-3. From this information a GIS database was created to include the most recent and readily available data on habitat and threat distributions.

Description of site-selection tool (MARXAN)

The MARXAN program uses basically three geospatial layers of information: 1) natural resource target distributions, 2) alteration factor distributions, and 3) a hexagon assessment grid. In this test case, each hexagon unit was equal to 57 acres. This size was considered appropriate due to the scale and resolution of the habitat maps and waterbody sizes.The natural resource targets and alterations factors were summarized by hexagon assessment unit (Examples are shown in Maps C-2 and C-3). The inputs to MARXAN include hexagon unit tables for natural resource target areas and areas of overlap with alteration factors. A total alteration layer was created before running the analysis. (Refer to the general methodology section and Appendix B for details on weighting methodology). Map C-4 shows a representation of the total alteration layer. The alteration layer incorporated the severity and extent of 15 different factors, although all were not present in each hexagon. Lower values correspond to less potential alteration, while higher values correspond to areas with more potential alteration. In the study area, the least altered areas were primarily located in Core and Back Sounds (Map C-4). An important cautionary note: when adding together different alteration factors that represent very similar impacts (e.g., development and shellfish closures), an overestimation of that impact can occur. Therefore, duplicative impacts were avoided as much as possible when selecting factors.

There were 19 categories of natural resource targets. MARXAN also requires a table showing the desired representation level for each natural resource target (Table C-4). A representation level of 30% was used as the average level, based on the literature; it was adjusted up or down based on rarity, vulnerability, or sensitivity of a habitat, or known or historic losses. A penalty factor is required by the program to ensure the levels are met. For this analysis the penalty factors were all set to 100.

Once the natural resource targets and total alteration layer were assembled (Step 3 in process), MARXAN was run at the tentative representation levels (Step 4 in process). The program was run for two different scenarios: (1) including inlet hydrologic units as targets and (2) excluding inlet hydrologic units as targets. A MARXAN analysis is generally repeated numerous times, since it is an iterative improvement process. In this case, the selected hexagons are accompanied by scores that indicate the frequency that 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 showed a "peppering" of many small areas. Such small areas are unacceptable as area designations. More enforceable management areas can be found by including a boundary length modifier (BLM) in the selection[4]. So the program was run again for the scenarios using a BLM of 0.05.

[4] A boundary length modifier is a program option used to create more aggregated selection of target areas.

Table C-2. Sources of data and preparation notes for natural resource targets used in Core/Bogue SHA test analysis.

Natural resource targets	Data sources	Preparation notes
SAV-high salinity species	Carraway and Priddy 1983; Ferguson and Wood 1994; DMF bottom mapping subtidal vegetated strata (1989-2003); and NWI aquatic beds class (1991-1992)	Includes specific NWI code L2AB3K3h (the 3 after K means mixohaline). Deleted areas overlapping with wetlands.
Shell bottom -intertidal high density shell	DMF bottom mapping (1989-2003) shell present strata joined with oyster density estimates	>100 shellfish/m^2 on intertidal shell bottom strata.
Shell bottom -intertidal low density shell		50-100 shellfish/m^2 on intertidal shell bottom strata.
Shell bottom -subtidal high density shell		>100 shellfish/m^2 on subtidal shell bottom strata.
Shell bottom -subtidal low density shell		50-100 shellfish/m^2 on subtidal shell bottom strata.
Wetlands -riverine forested wetlands	DCM wetlands mapping (1994) selecting from only estuarine, riverine, or headwater wetland hydrogeomorphic categories	Bottomland hardwood forest and riverine swamp forest (note: included both modified and unmodified).
Wetlands -freshwater marsh		Did not differentiate between freshwater tidal and freshwater non-tidal marsh (not available in primary data source). Added one small freshwater marsh area that was impounded
Wetlands -salt/brackish marsh		In addition to salt/brackish marsh category, also included human impacted (DCM class) mixohaline marshes (NWI classification).
Wetlands -estuarine shrub/scrub		
Wetlands -estuarine forested		
Wetlands -headwater wetlands and adjacent flats (including pocosins)		Headwater swamps only (pocosins included huge, relatively dry areas).
Wetland edge	NWI maps (1991-1992)	Represents edge of intertidal wetland vegetation

Table C-2. (Continued)

Natural resource targets	Data sources	Preparation notes
Inlet connectivity	USGS hydrologic units maps	Selected all natural resource target areas within 12-digit HUs that contained an inlet.
Linear water features (streams, creeks)	National Hydrologic Dataset medium resolution sub-basin coverage	Anything upstream of the wetland-water interface line (excluding obvious ditches in areas landward of wetland targets). Added connector on tributary of Newport River.
Non-wetland shoreline	NWI maps (1991-1992)	The line separating uplands from non-vegetated intertidal shorelines or subtidal bottom.
Soft bottom-Estuarine intertidal sand		Included NWI code E2US2. Deleted areas overlapping with wetlands or SAV
Soft bottom-Estuarine intertidal mud		Included NWI code E2US3. Deleted areas overlapping with wetlands or SAV
Soft bottom-Estuarine subtidal unconsolidated bottom		Combined NWI codes E1UB2 and E1UB3 because very few subtidal areas had sand/mud subclassification. Deleted areas overlapping with wetlands or SAV.
Soft bottom-freshwater (riverine or lacustrine impounded)		Includes unconsolidated bottom of impoundments and river bottoms absent in linear water features. Added small area of riverine bottom in Newport River. Added some very small contiguous freshwater bottom areas classified as PUB3 (impounded).

Table C-3. Summary unit, impact severity, data source, and preparation notes for alteration factors used in the Core/Bogue SHA analysis.

Summary unit for analysis	Activity/factor	Severity of impact*					Data source	Preparation notes
		Soft bottom	SAV	Wetlands	Shell bottom	Water column		
Hexagons	Culverts	0	1	2	1	2	N.C. Dept. of Transportation culvert database (2003)	Comprised of all natural resource targets upstream from culverts.
	Dams/ impoundments	1	0	3	0	2	National Wetland Inventory maps (NWI) (1991-1992)	Use NWI code **h** modifier (diked/impounded) for specific natural resource areas, and added all streams and wetlands upstream from impounded area.
	Ditching/drainage/ channelization	0	0	2	1	1	NWI maps (1991-1992)	Use NWI code **d** modifier (partially drained) for specific natural resource areas, and added all streams and wetlands upstream from ditched/drained/channelized area
	Forestry	0	1	2	2	2	N.C. Div. Coastal Management wetland maps (1994)	Used cutover/cleared modifier for specific wetland areas
	Boating activity	0	1	1	1	1	NOAA navigation charts and digital ortho quads (1993-1994)	Connected navigation buoys and included dredge channels indicated on aerial photography. Applied 200m buffer to linear features to indicate area of potential impacts. Buffer cut to within subtidal-intertidal areas only.

Table C-3. (Continued)

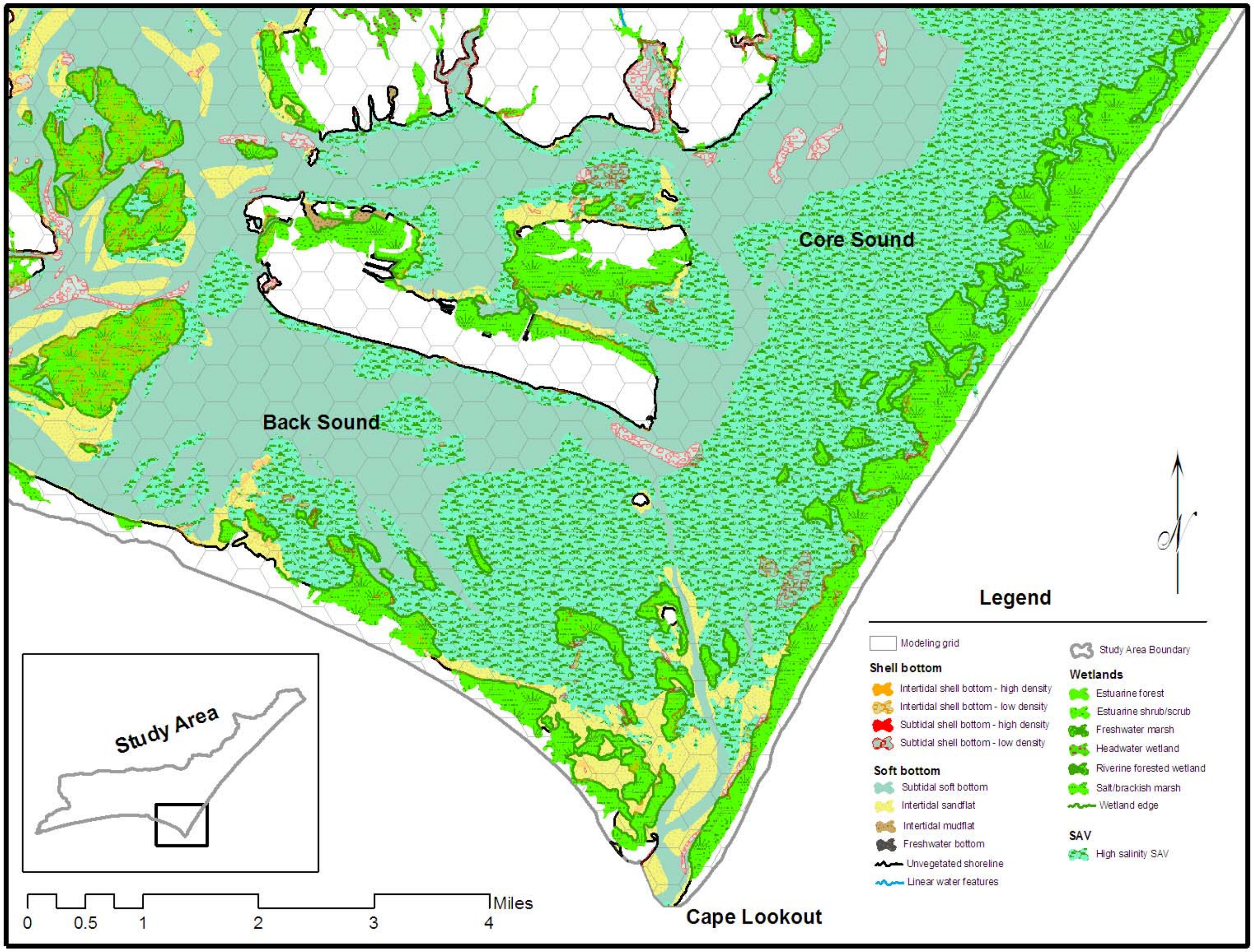
Summary unit for analysis	Activity/factor	Severity of impact*					Data source	Preparation notes
		Soft bottom	SAV	Wetlands	Shell bottom	Water column		
Hexagons	Bottom trawling	1	2	0	2	1	N.C. Div. Marine Fisheries (DMF) area designations (2004)	Used trawl net prohibited, and primary nursery area coverages to subtract from NWI subtidal areas - indicates potential trawling areas. Included some prohibited areas by proclamation (SH-5-2006).
	Navigation channels and inlet dredging	1	2	2	2	1	U.S. Army Corp of Engineers (COE) dredge channel map (2003)	
	Clam kicking	1	2	0	2	1	DMF area designations (2000)	
	Ports	2	0	0	1	1	COE dredge channel map (2003)	Used selected area from COE dredge channel map
	Conditionally approved closed	0	2	0	1	1	DEH-SS Shellfish Closure maps (2006)	
	Conditionally approved open	0	1	0	0	0		
	Permanent closures	1	3	0	2	2		

Table C-3. Continued…

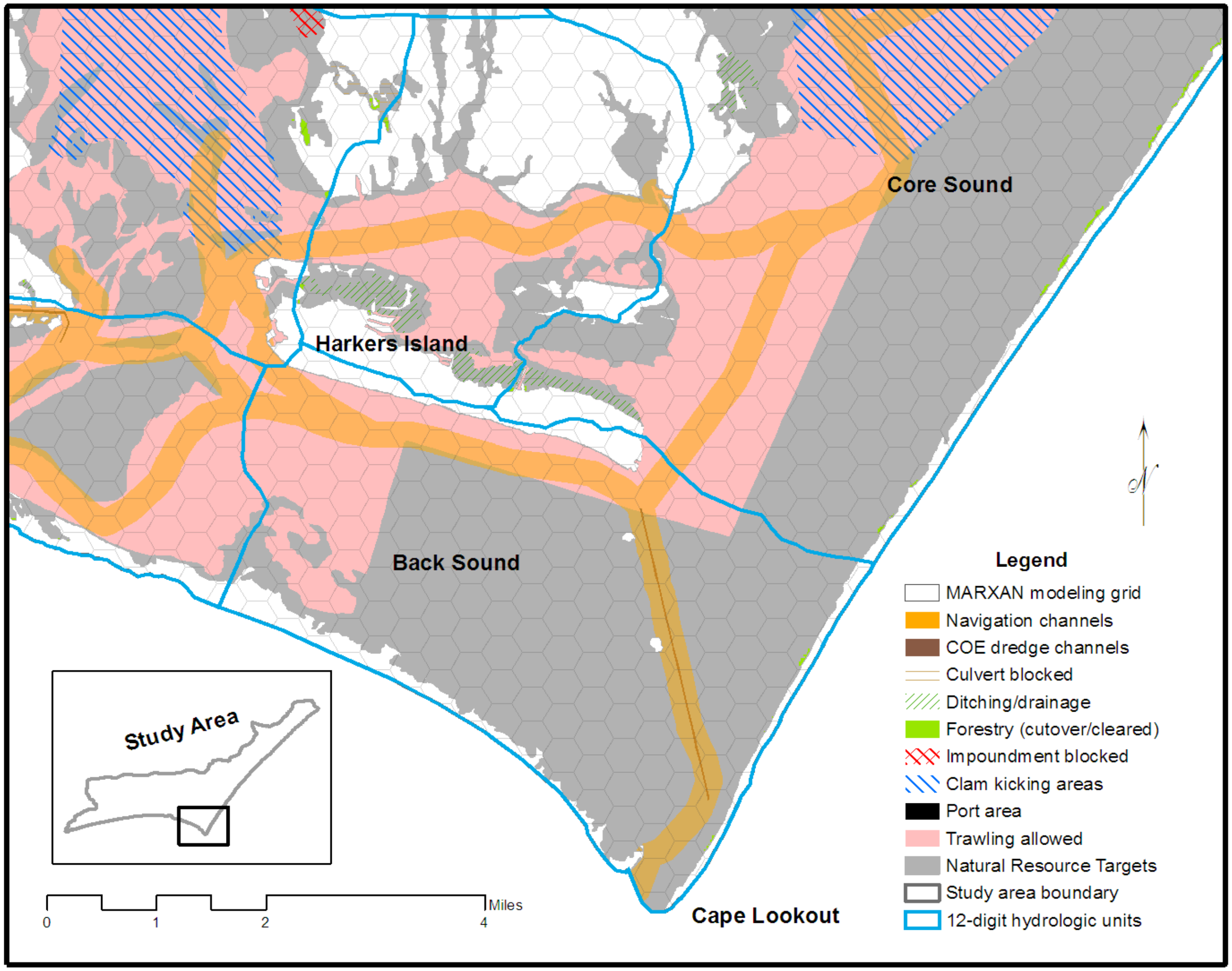
Summary unit for analysis	Activity/factor	Severity of impact*					Data source	Preparation notes
		Soft bottom	SAV	Wetlands	Shell bottom	Water column		
12-digit hydrologic units	Cropland	1	2	2	1	2	C-CAP 1997 land use/land cover map (NOAA)	Used cultivated land classification, and calculated % of 12-digit HU area. Reverted from categorical E value.
	Impervious surfaces - stormwater runoff	1	3	1	3	3	C-CAP 1997 land use/land cover map (NOAA)	Used high intensity developed + low intensity developed, and calculated % of 12-digit HU area. Reverted from categorical E value.
	Land use change	1	2	3	2	2	C-CAP 1991-1997 land use/land cover change map (NOAA)	% of 12-digit HU land area converted to low or high intensity developed from an open space classification and calculated % of 12-digit HU area. Reverted from categorical E value.

* Severity codes: 0=none or not rated, 1=minor, 2=moderate, 3=severe

Map C-2. Small subarea of the study area showing the distribution of natural resource targets.



Map C-3. Small subarea of the study area showing the distribution of water-based alteration factors.



Map C-4. Map of total alteration layer. Note the color groups contain a range of alteration values.

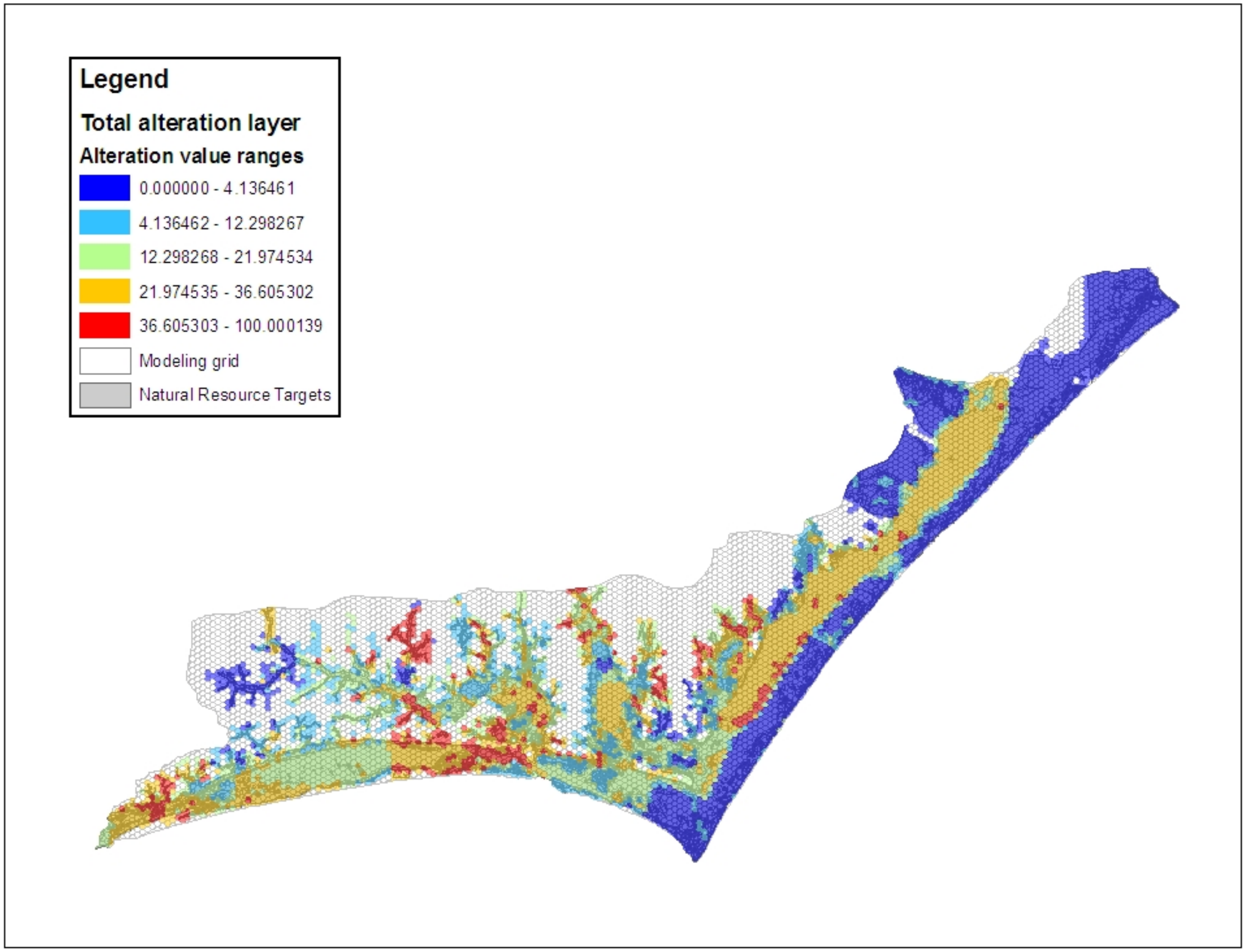


Table C-4. Representation levels for natural resource targets used in the Core/Bogue SHA analysis.

Habitat type	Natural resource target	Representation level Percent	Rationale
Shell bottom	Intertidal low density	**30%**	Average level from literature
	Intertidal high density	**50%**	Above average due to harvest vulnerability
	Subtidal low density	**30%**	Average level from literature
	Subtidal high density	**50%**	Above average due to rarity and historic losses
Soft bottom	Estuarine intertidal mud	**30%**	Average level from literature
	Estuarine intertidal sand	**30%**	Average level from literature
	Estuarine subtidal	**10%**	Below average due to abundance and resilience
	Freshwater bottom	**30%**	Average level from literature
	Unvegetated shoreline	**30%**	Average level from literature
Wetlands	Estuarine shrub/scrub	**30%**	Average level from literature
	Estuarine forest	**30%**	Average level from literature
	Riverine forest	**50%**	Above average due to relative vulnerability to development
	Salt/brackish marsh	**30%**	Average level from literature
	Freshwater marsh	**30%**	Average level from literature
	Headwater wetland	**50%**	Above average due to relative vulnerability to development
	Wetland edges	**30%**	Average level from literature
SAV	High salinity grasses	**70%**	Above average due to sensitivity and importance as concern species habitat
Water column	Linear water features	**30%**	Average level from literature
	Inlet hydrologic units	**50%**	Above average due to connectivity function

For simplicity, we used the Arcview extension CLUZ (Smith 2004) to perform the MARXAN analysis. CLUZ consists of two parts. The first part acts as an ArcView GIS interface for the MARXAN conservation planning software, and the second allows on-screen conservation planning. The interface for MARXAN is designed to be easily understood by beginners and does not give all of the possible MARXAN options. Specifically, it uses default values for some of the alteration functions, it assumes that representation levels for all of the natural resource targets should be fully met, and it does not allow the use of more specialized planning algorithms. Future analyses that include stratification and clustering may require the full functionality of MARXAN.

Results of computer analysis

The committee selected the "no inlets with BLM" scenario because it appeared to result in the best aggregation of areas (Map C-5). All the natural resource targets attained or exceeded their representation level in the two "no inlet" scenarios reported here (Table C-5). However, the average alteration level of selected hexagons differed among scenarios. In general, the average alteration increased with the inclusion of a boundary length modifier. The increased alteration is due to the inclusion of small areas with higher alteration levels in the aggregated selections. This increased alteration is offset by the enhanced system connectivity and enforcement potential for the areas.

Map of preferred scenario investigated

Map C-5 shows a paucity of selections in Bogue Sound, which occurred under all scenarios. To ensure some portion of area within Bogue Sound was selected, the targets could be stratified by waterbody or area, and higher alteration values in Bogue Sound could be manually selected. For this test case, the latter method was used to select some areas in Bogue Sound. The committee agreed that if this were an actual analysis, they would re-run with stratification to ensure selection within Bogue Sound, which is somewhat hydrographically separated from Core Sound.

To review map results, the regional expert panel examined the natural resource targets, selection scores, and alteration values of the selected hexagon units. Map C-6 shows selection scores for the entire area under the preferred scenario. This map is useful when manually revising selections because it represents an integrated summary of both target occurrence and alteration factors. Selected hexagons with high selection scores indicate a high probability that the selected area is truly strategic. Map C-7 shows the alteration level associated with areas selected by MARXAN in the preferred scenario. Selected areas with less alteration (blues and green) suggest exceptional SHAs, whereas selected areas with more alteration (orange and red) suggest at-risk SHAs.

Map C-5. MARXAN selections excluding inlets and using 0.05 boundary length modifier.

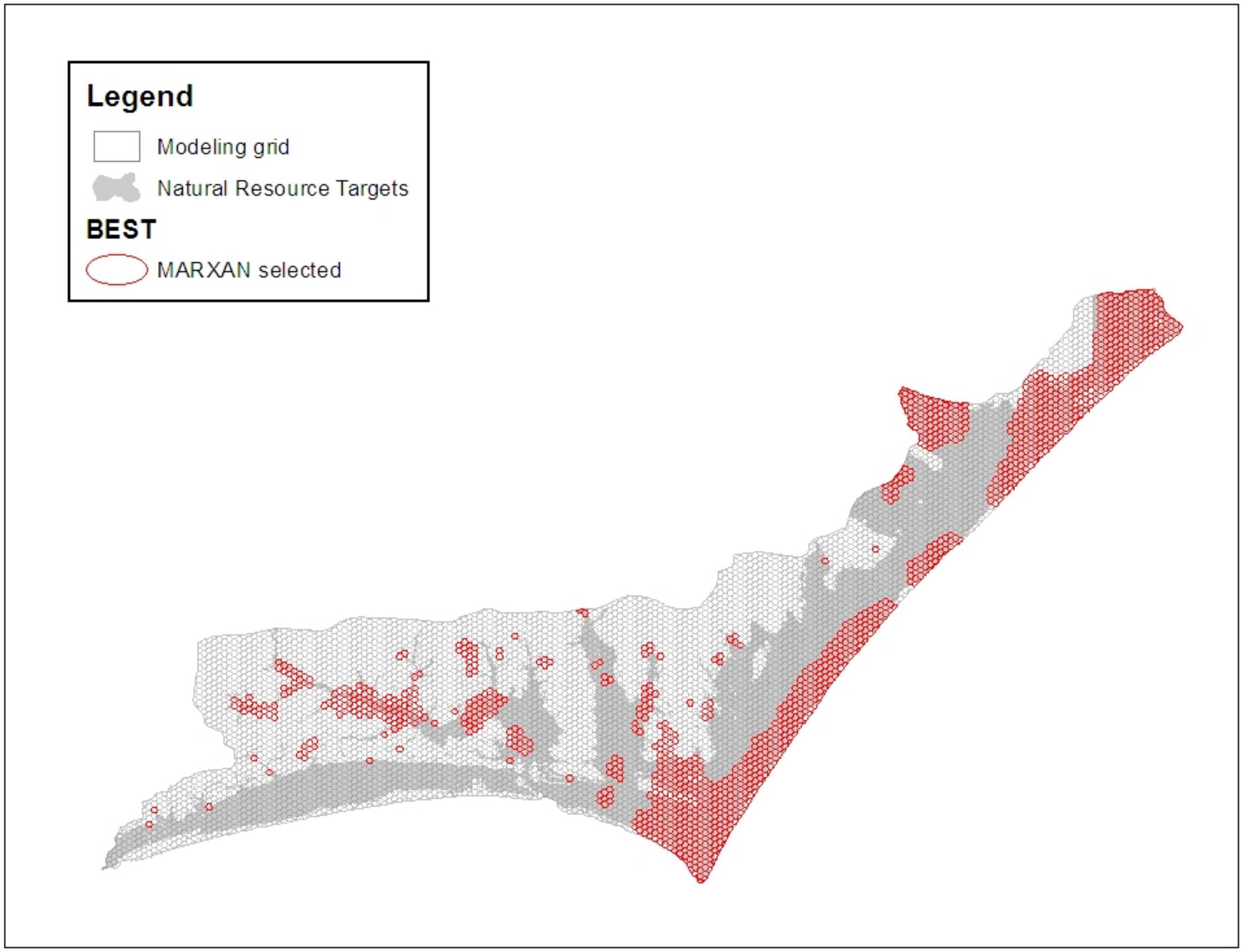
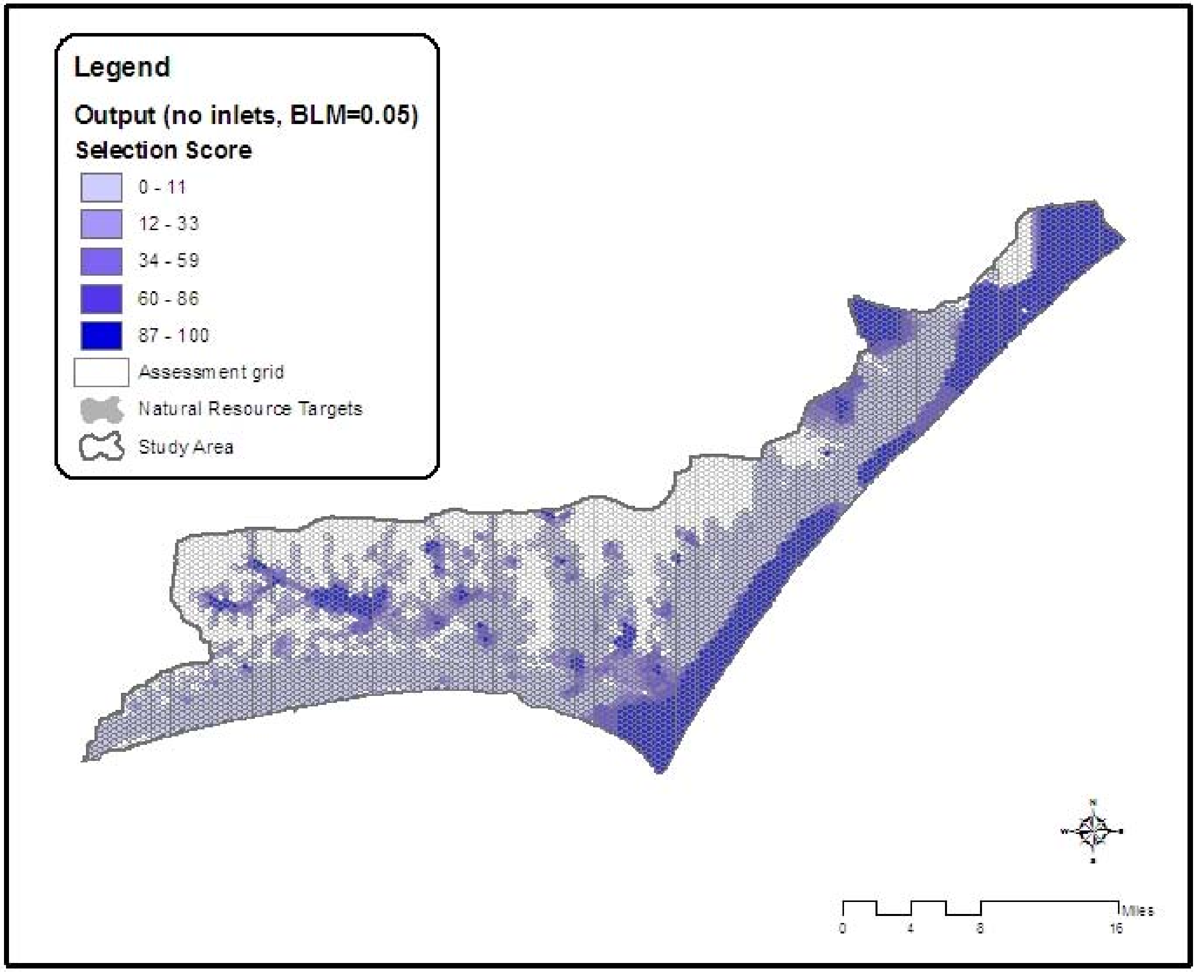


Table C-5. Results of the Core/Bogue SHA analysis: representation levels attained and average alteration score of selections in two scenarios examined.

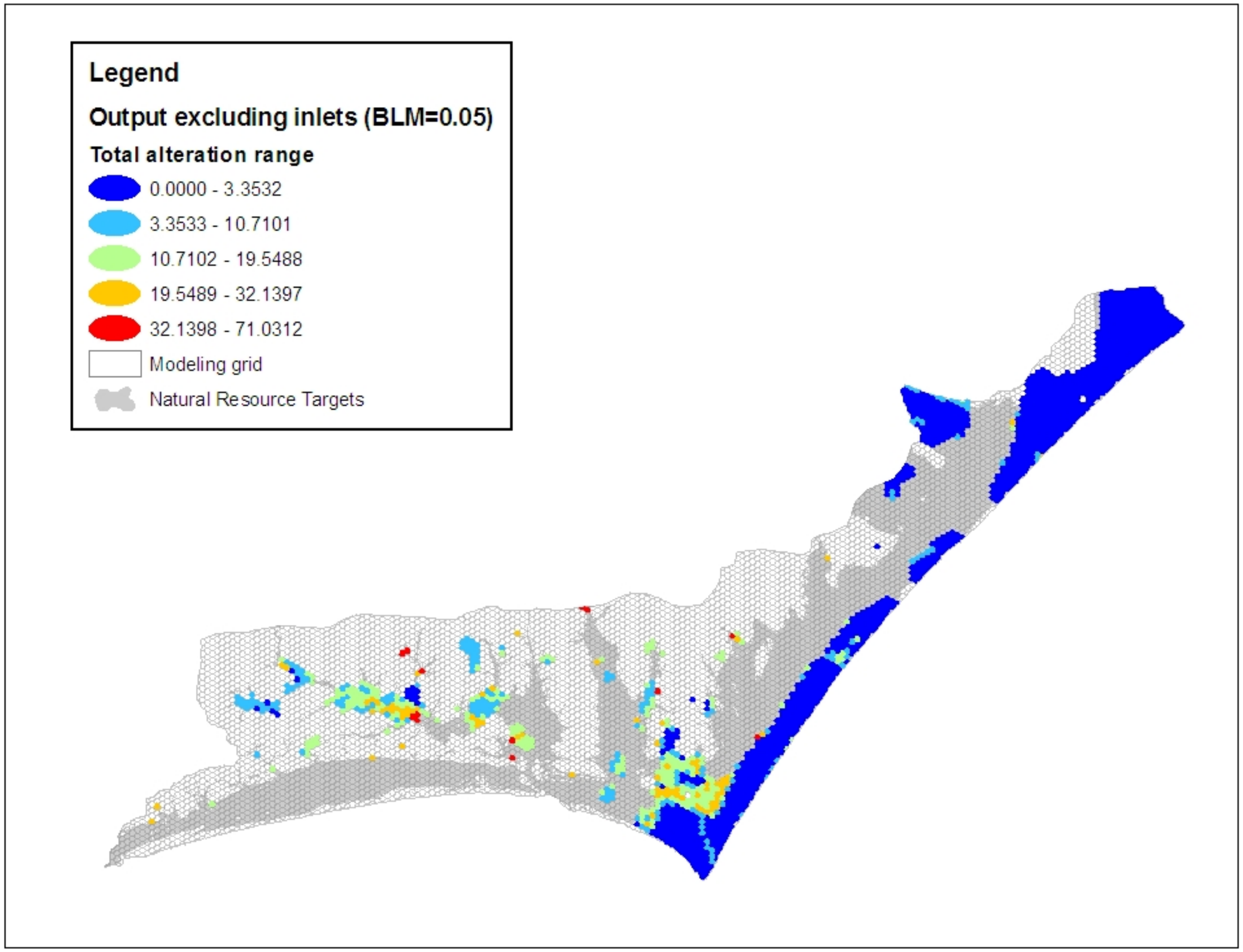
Habitat type	Natural resource target (measurement unit)	Total area/ distance	Representation level Percent	Selected with 0-BLM* Amount	Selected with 0-BLM* Percent	Selected with 0.05-BLM* Amount	Selected with 0.05-BLM* Percent
Shell bottom	Intertidal low density (ac)	**1005.51**	**30%**	302.968	30%	309.819	**31%**
	Intertidal high density (ac)	**607.83**	**50%**	304.183	50%	304.974	50%
	Subtidal low density (ac)	**5432.69**	**30%**	1630.063	30%	1631.691	30%
	Subtidal high density (ac)	**29.78**	**50%**	15.018	50%	15.062	**51%**
Soft bottom	Estuarine intertidal mud (ac)	**48.90**	**30%**	23.132	**47%**	16.159	**33%**
	Estuarine intertidal sand (ac)	**9740.39**	**30%**	4166.603	**43%**	6319.708	**65%**
	Estuarine subtidal (ac)	**81756.53**	**10%**	8176.65	10%	14159.125	**17%**
	Freshwater bottom (ac)	**97.93**	**30%**	56.184	**57%**	66.158	**68%**
	Unvegetated shoreline (m)	**280706.45**	**30%**	84221.188	30%	84300.854	30%
Wetlands	Estuarine shrub/scrub (ac)	**4803.26**	**30%**	1441.823	30%	1771.802	**37%**
	Estuarine forest (ac)	**57.28**	**30%**	30.804	**54%**	35.338	**62%**
	Riverine forest (ac)	**5219.81**	**50%**	2610.453	50%	2613.822	50%
	Salt/brackish marsh (ac)	**30507.15**	**30%**	9152.847	30%	11427.182	**37%**
	Freshwater marsh (ac)	**0.92**	**30%**	0.918	**100%**	0.918	**100%**
	Headwater wetland (ac)	**1978.95**	**50%**	990.92	50%	990.326	50%
	Wetland edges (m)	**763702.82**	**30%**	270535.904	**35%**	351771.208	**46%**
SAV	High salinity grasses (ac)	**38584.38**	**70%**	27010.627	70%	27010.087	70%
Water column	Linear water features (m)	**229463.48**	**30%**	68843.251	30%	68839.531	30%
Average alteration level				3.91		4.89	

*BLM = Boundary length modifier

Map C-6. MARXAN selections scores excluding inlets and using 0.05 boundary length modifier.



Map C-7. The degree of alteration associated with areas selected by MARXAN (excluding inlet hydrologic units and BLM=0.05).



Corroboration and identification

The map with the "computer-selected" SHAs was visually compared to the 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 process). The biological data used in this phase of the analysis are listed in Table C-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 that the area was of 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 C-6. Programs documenting fish abundance and designation indicating exceptional aquatic habitats in Core/Bogue sounds area.

Corroboration type	Data theme	Data source	Preparation notes
Biological data	Blue crab nurseries	DMF biological database (Program 120)	Only presence depicted
	Finfish nurseries	DMF biological database (Program 120)	Only presence depicted
	Shrimp nurseries	DMF biological database (Programs 120 & 510)	Only presence depicted
	Bay scallop habitat	DMF biological database (Program 635)	Areas where subsampling estimates greater than 0.5 bay scallop/m^2
Biological designations	Primary nursery areas	DMF rule designation	
	Significant Natural Heritage Areas	Natural Heritage Program	
	Outstanding Resource Waters	DWQ rule designation	

The committee clumped selected hexagons of similar alteration level into manageable polygons for the corroboration and identification process. In the future, the regional expert panels should examine maps of both the selection scores and alteration ratings for guidance during the manual selection phase. Nineteen polygons were delineated (Maps C-8 to C-10). Polygons 1-15 include hexagons selected by the computer analysis. Polygons 16-19 were added by the regional expert panel during the identification process. For each polygon, the regional panel considered 1) the current habitat condition, 2) available supporting data for that polygon, and 3) whether the polygon was adequately protected from known threats. A short justification is provided below for inclusion of each site.

SHA nominations

Areas 1 & 4 (northeast Core Sound) These two areas were connected due to supporting data.
Condition: Both had an abundance of SAV, little alteration
Corroboration: Adjacent to Cape Lookout National Seashore, designated as ORW by EMC rule
Threats/protection: Some fishing related threats, very undeveloped

Area 2 (Cedar Island Bay)
Condition: SAV, wetlands, and shell bottom
Corroboration data: Nursery and refuge function, designated SNHA, and documented fish use
Threats/protection: Imminent development risk

Area 3 (Thoroughfare Bay)
Condition: Wetlands, shell bottom
Corroboration data: SNHA, fish data, shellfish lease (?)
Threats/protection: Development risk

Areas 5 & 6 (south end Core Sound, Back Sound, The Straits)
Condition: Excellent – SAV, wetlands, sand flats, shell bottom, near inlet
Corroboration data: ORW, protected lands adjacent, bay scallop data
Threats/protection: Development risk on Harker's Island and down east mainland communities

Area 7 (Ward's Creek)
Condition: Headwater wetlands, shell bottom
Corroboration data: PNA, SNA, fish data, North River Farms upstream
Threats/protection: ?

Area 8 (Middle Marsh, lower North River marshes)
Condition: Wetlands, shell bottom, SAV
Corroboration data: Close to NERR sites- connectivity, SNHA
Threats/protection: SAV dredging ?

Area 9 Newport Marshes (hexagons expanded to include all of marsh)
Condition: Marsh, shell
Corroboration data: Fish data, open to shellfishing, NMFS fish data on southern flounder
Threats/protection: ?

Area 10 (Cross Rock, Newport River)
Condition: Shell bottom, shellfish leases
Corroboration data: Shrimp data, PNA, fish data
Threats/protection: Waste water treatment plant, sediment, trawling (some)

Area 11 (headwater wetlands of Harlowe Creek)
Condition: Headwater wetlands, no one very familiar with that specific site

Corroboration data: PNA, SNA adjacent to Croatan National Forest
Threats/protection: ?

Areas 12 & 13 (Newport River riverine wetlands upstream of Cross Creek)
Condition: Wetlands, linear water features
Corroboration data: SNHA, upstream of important shell bottom, Bill Kirby-Smith report compares to White Oak River
Threats/protection: Hog farm, sprayfield

Area 14 (Gales Creek)
Condition: Wetlands, SAV
Corroboration data: PNA
Threats/protection: Closed to shellfishing, development threat

Area 15 (Upper Newport River)
Condition: Headwater wetlands
Corroboration data: Inland waters- no DMF data
Threats/protection: Few threats – adjacent to Croatan National Forest

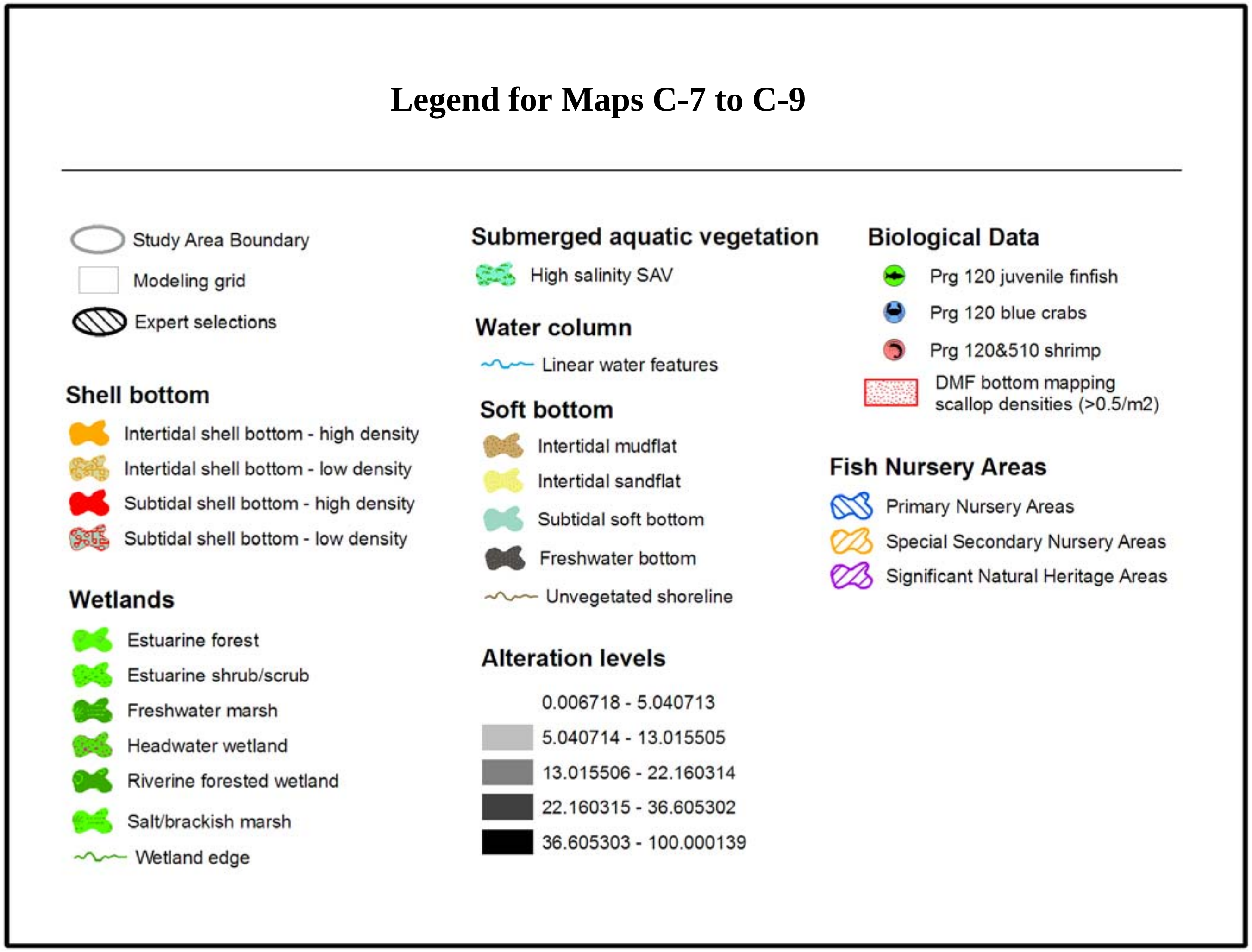
Area 16 (west end Bogue Sound)
Condition: SAV, wetlands
Corroboration data: Bay scallop data, fish data, some is PNA, SNHA, ORW
Threats/protection: Intense development, some trawling

Area 17 Bogue banks, central Bogue Sound (adjacent to Roosevelt Natural Area and Aquarium)
Condition: SAV, wetlands, shell bottom
Corroboration data: ?
Threats/protection: Development, some trawling

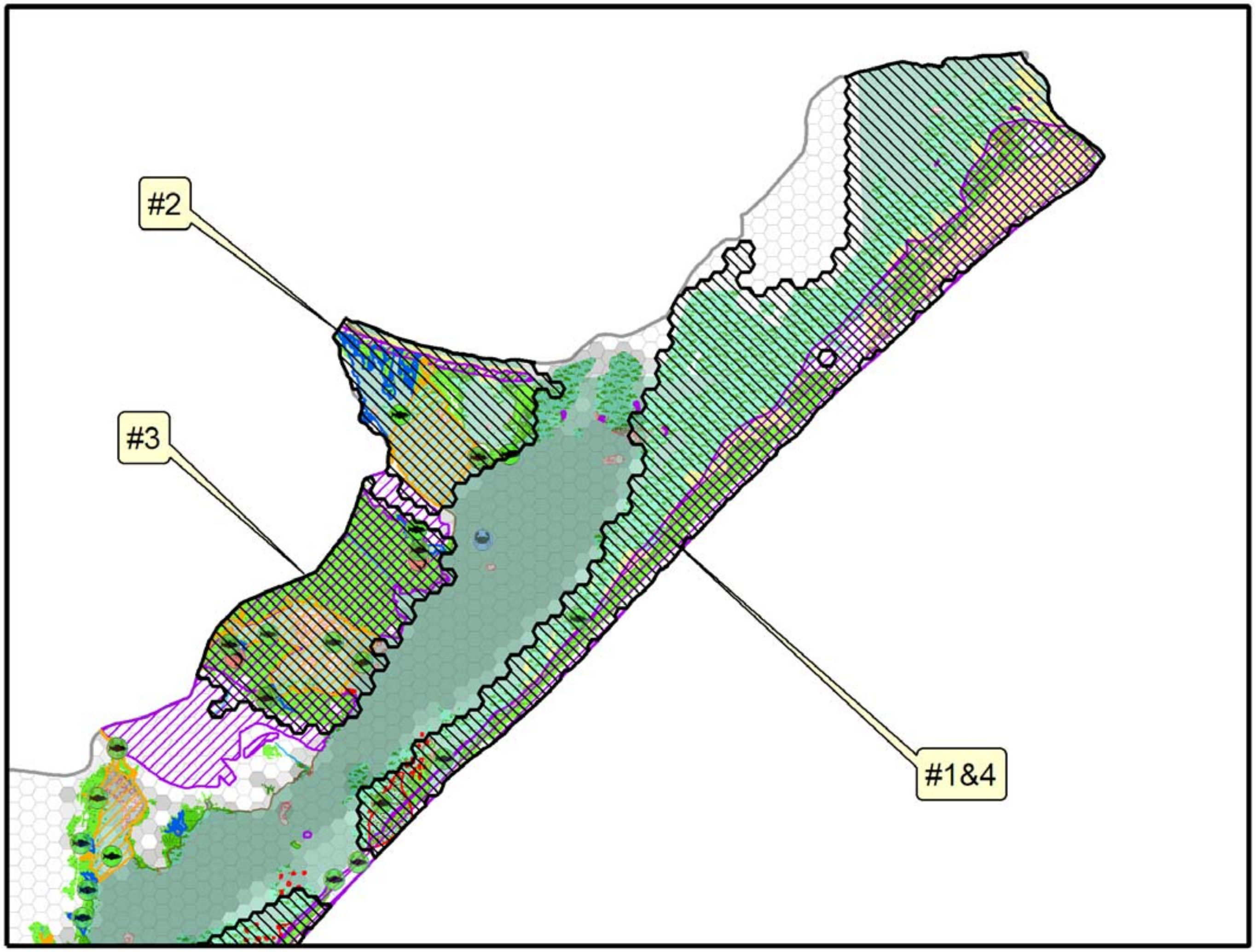
Area 18 (Hoop Hole Creek)
Condition: shell bottom, SAV, wetlands
Corroboration data: open to shellfish harvest
Threats/protection: development

Area 19 (Tar Landing – behind Ft. Macon)
Condition: Shell bottom, SAV, wetlands
Corroboration data: Open to shellfish harvest, fish data ?
Threats/protection: Development

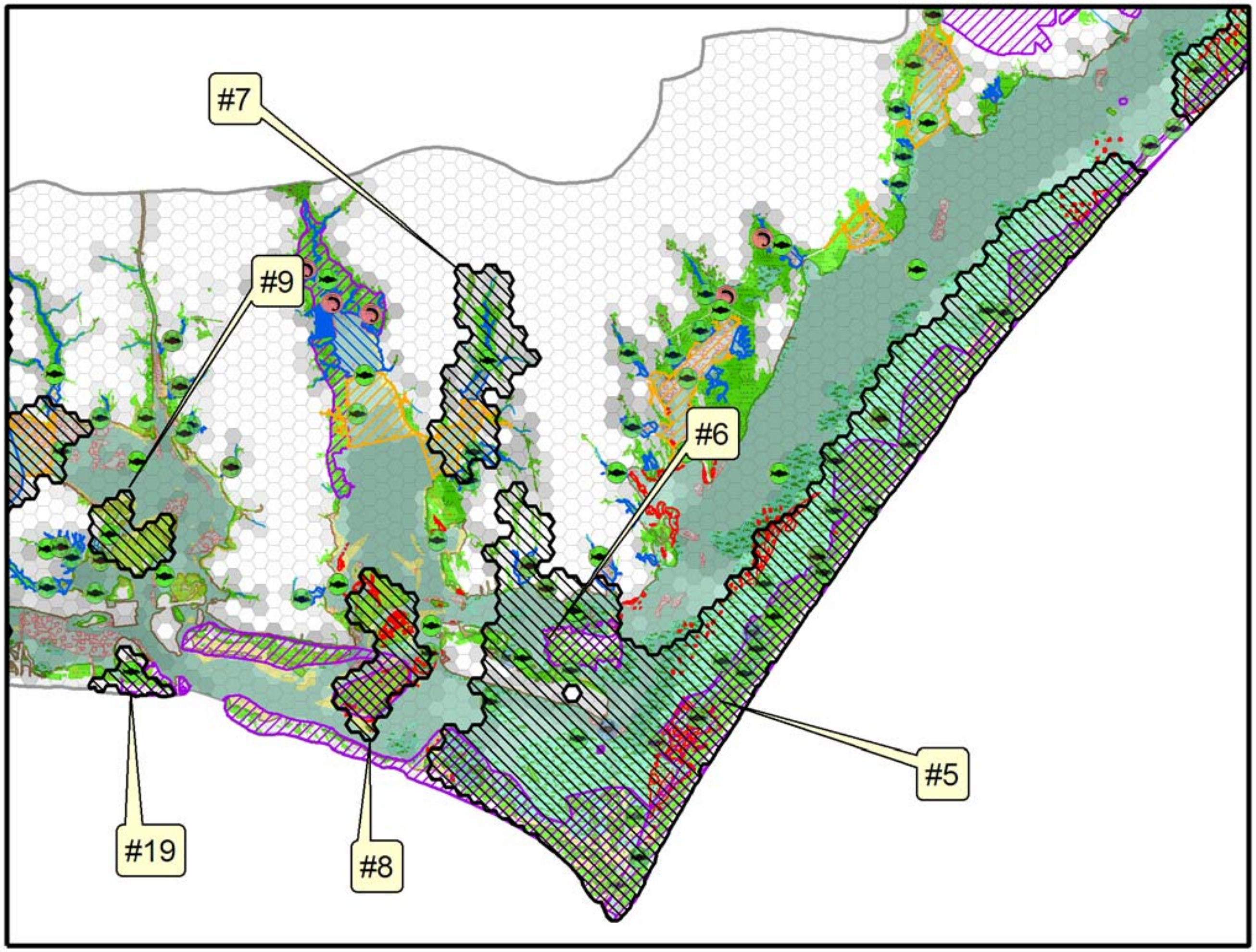
Figure C-1. Reference for subsequent maps.



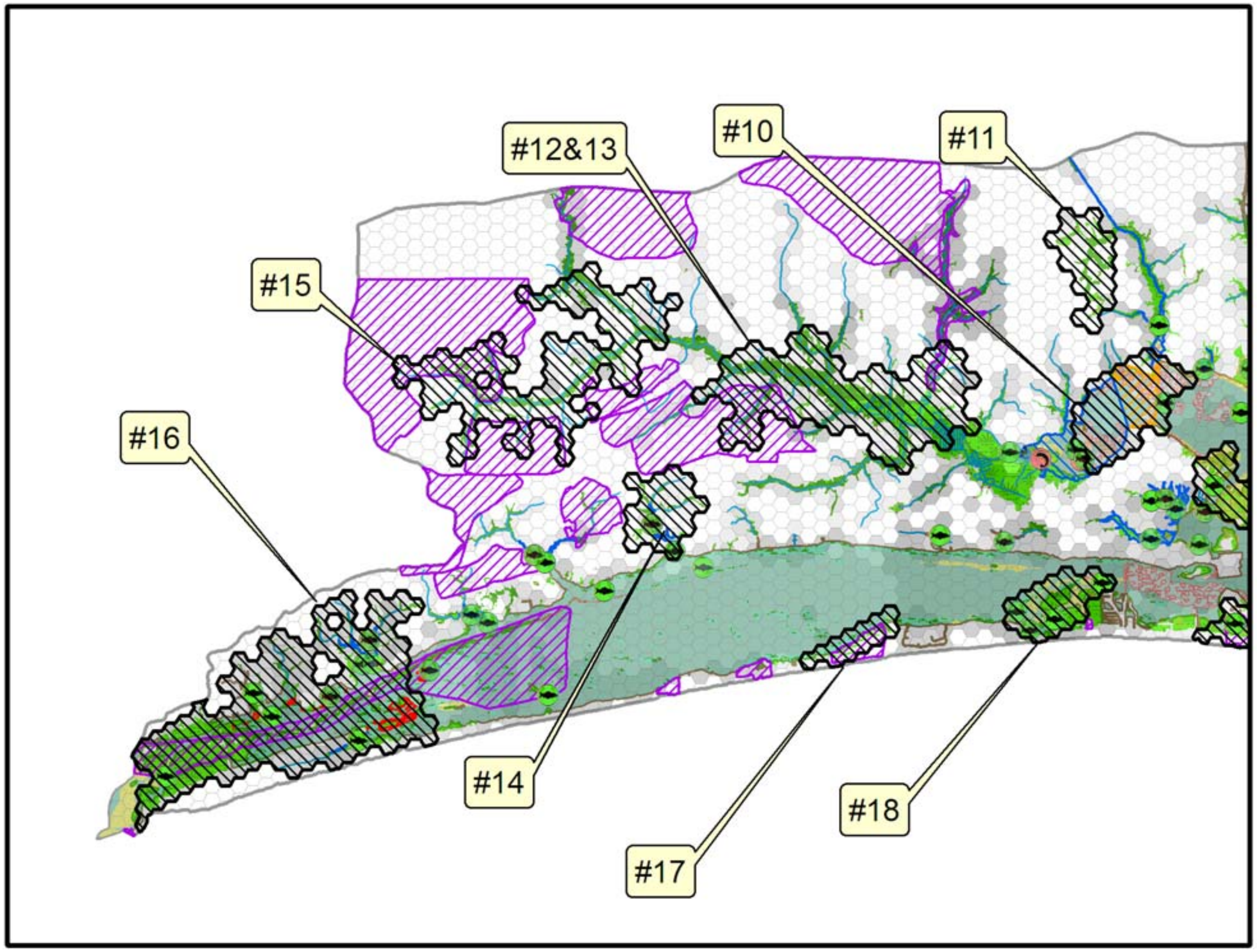
Map C-8. Areas in northern Core Sound selected as SHAS candidates by the expert panel.



Map C-9. Areas in southern Core Sound, Back Sound, and tributaries selected as SHAS candidates by the expert panel.



Map C-10. Areas in western Bogue Sound selected as SHAS candidates by the expert panel.



Effect of manual modifications

The manual modifications to the preliminary "computer-selected" sites generally resulted in enlargement of the selected SHAs, primarily for contiguity and enforcement reasons, but also to include some important natural resource targets that were under-represented (Table C-7). Freshwater bottom, headwater wetlands, estuarine forest, subtidal shell high density, and freshwater marsh were under-selected by 16-30%. In particular, freshwater marsh and subtidal shell high density were the most under-represented in the manual selections, probably due to their relatively small acreage, isolation and ecological condition. Of the 30 acres of subtidal shell high density in the study area, only about 22% of that target was identified for SHA designation in the final results. In order to reach the representation levels for each target, the regional expert panel should discuss if additional areas including those under-represented targets should be added to the SHA network. Those areas could be added manually or by re-running the program with higher representation levels or earmarking the manual selections for mandatory selection to capture an adequate amount of each target.

The manual additions also increased the total area of the potential SHA network. While approximately 40% of the total natural resource target area was selected by MARXAN, over 50% was captured after manual modifications were made. When determining SHAs and their boundaries, the panel took into account the need for units that are hydrologically holistic, as well as location specific. In other words, the committee selected some units with broader, land-based alterations in mind (i.e., hydrologically holistic) whereas others were selected for contiguous habitat area. The approach may vary regionally depending on the distribution of habitats, alteration factors, and corroborating biological data.

Table C-7. Natural resource target areas captured in the corroboration and manual modification phase of the analysis. The difference between desired representation level and actual percent of target that was selected are sorted in order of positive to negative.

Natural Resource Targets	Area/distance selected	% of total area/distance	Representation level (%)	Difference
Estuarine intertidal sand (ac)	7131.94	73	30	43
Wetland edges (m)	494474.47	65	30	35
Salt/brackish marsh (ac)	18100.69	59	30	29
Estuarine shrub/scrub (ac)	2707.61	56	30	26
Intertidal shell low density (ac)	478.39	48	30	18
Estuarine subtidal (ac)	20540.29	25	10	15
Riverine forest (ac)	3240.04	62	50	12
Linear water features (m)	92988.03	41	30	11
Unvegetated shoreline (m)	109540.78	39	30	9
Subtidal shell low density (ac)	2035.28	37	30	7
High salinity grasses (ac)	29438.19	76	70	6
Estuarine intertidal mud (ac)	17.17	35	30	5
Intertidal shell high density (ac)	327.55	54	50	4
Freshwater bottom (ac)	13.63	14	30	-16
Headwater wetland (ac)	655.60	33	50	-17
Estuarine forest (ac)	6.03	11	30	-19
Subtidal shell high density (ac)	6.52	22	50	-28
Freshwater marsh (ac)	0.00	0	30	-30

Proposed SHAs

Description and class (at-risk and/or exceptional)

Sixteen distinct areas were identified for SHA nomination as described above. Areas 1-15 were selected by the computer program and had alteration levels ranging from 0 to 20.5 (dark blue, light blue, and green color coding in Map C-6). These areas should be classified as Exceptional SHAs. Areas 16-19 were not selected by the computer but were added by the expert panel to include appropriate representation in Bogue Sound. These areas were known to have worthy corroborating information to support designation. However, the alteration levels were higher than the previous group, ranging from 4 –to 36 (light blue to orange code), with a few areas slightly higher (red code).

Rules-boundary defined

To be determined by appropriate management authorities.

Recommended management strategy

To be determined by appropriate management authorities

APPENDIX D: GLOSSARY OF IMPORTANT TERMS AND ACRONYMS

TERMS	
Algorithm	An often complex, computable mathematical procedure that includes repetitive running of a series of steps to achieve a near-optimal result.
Alteration levels	An index of the total amount of anthropogenic modifications impacting a hexagon assessment unit. Equivalent to "cost" in MARXAN terminology.
Boundary length modifier	A program option used to control the spatial aggregation of selected sampling units (hexagons). Values greater than 0 encourage solutions that aggregate sampling units into compact clusters with shared boundaries.
CHPP Steering Committee	Inter-commission committee consisting of two representatives each of the MFC, CRC, and EMC, charged with facilitating CHPP-related implementation actions.
Ecoregional assessment	An evaluation conducted over a relatively large area of land and water that contains geographically distinct assemblages of natural communities and functions.
Hexagon assessment unit	The area-based assessment unit (polygon) used in the optimal site-selection program and attributed with the amount and quality of the natural targets and alteration factors within them. Hexagons in the test case represented 57 acres.
Land-based alteration factors	Activities, features, or water quality parameters that can affect boundary delineation or quality of the areas being considered for designation that occur on the land, but affect the aquatic system (e.g. impervious surface).
MARXAN	Site-selection computer software program originally developed to aid in design of marine reserve systems.
Natural resource targets	Habitats or ecological functions that are identified as a priority for protection, enhancement, or restoration. Equivalent to "coarse conservation targets" in MARXAN terminology.
Representation level	The portion of natural resource target X desired for representation by the site-selection program. Equivalent to "conservation goal" in MARXAN terminology.
Selection score	The frequency a hexagon assessment unit was selected in X number of runs. Equivalent to "conservation score" in MARXAN terminology.
Selections	Hexagon assessment units included in meeting the selection levels for all the natural resource targets in an analysis
Total alteration layer	Program input estimating the combined effect of multiple alteration factors on each hexagon assessment unit. Equivalent to "cost layer" in MARXAN terminology.
SHA Advisory Committee	MFC-appointed committee of scientists charged to develop the process for identification of SHAs.
SHA Management Committee	MFC-appointed committee proposed for establishment to manage the SHA process

SHA Regional Expert Panel	Panel of scientists and resource managers with scientific knowledge of the specific region being assessed for SHA identification. Will work with DMF staff and SHA Management Committee to provide input on natural resource targets and alteration factors, and review and refine results to identify SHAs.
Water-based alteration factors	Activities, features, or water quality indicators that can affect boundary delineation or quality of the areas being considered for designation that occur on the water and also affect the water (e.g. trawling)
ACRONYMS	
C-CAP	NOAA's Coastal Change Analysis Program
COE	U.S. Army Corp of Engineers
CRC	N.C. Coastal Resource Commission
DCM	N.C. Division of Coastal Management
DEH-SS	N.C. Division of Environmental Health – Shellfish Sanitation
DMF	N.C. Division of Marine Fisheries
DOT	N.C. Department of Transportation
DWQ	N.C. Division of Water Quality
EMC	N.C. Environmental Management Commission
HQW	High Quality Waters (designated by EMC)
MFC	N.C. Marine Fisheries Commission
MPA	Marine Protected Area
NOAA	National Oceanographic and Atmospheric Administration
NWI	National Wetlands Inventory
ORW	Outstanding Resource Waters (designated by EMC)
PNA	Primary Nursery Area (designated by MFC)
SHA	Strategic Habitat Area
SNHA	Significant Natural Heritage Area
USGS	U.S. Geological Survey