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Conservation in the Carolinian Ecoregion

An Ecoregional Assessment 2005




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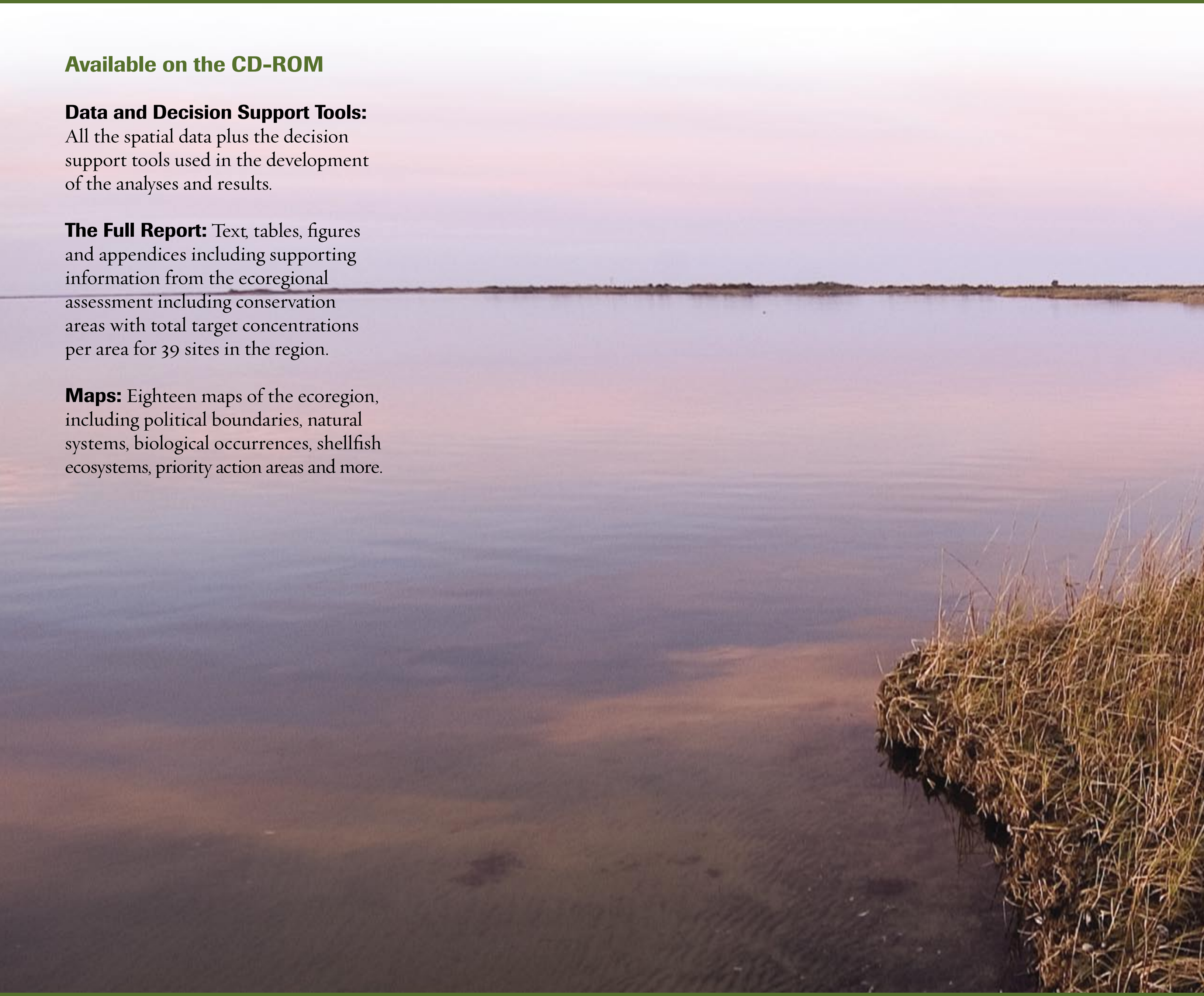

Available on the CD-ROM

Data and Decision Support Tools: All the spatial data plus the decision support tools used in the development of the analyses and results.

The Full Report: Text, tables, figures and appendices including supporting information from the ecoregional assessment including conservation areas with total target concentrations per area for 39 sites in the region.

Maps: Eighteen maps of the ecoregion, including political boundaries, natural systems, biological occurrences, shellfish ecosystems, priority action areas and more.

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An Ecoregional Assessment 2005

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An Ecoregional Assessment

March 2005

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– **Jeff DeBlieu**
Outer Banks, NC
April 2005

Preface

The mission of The Nature Conservancy is to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Recognizing that a focus on the marine environment is critical to achieving our mission, TNC has made an organizational commitment to expand its marine conservation efforts and capacity both nationally and internationally.

In the sea as on land, The Nature Conservancy identifies important sites for the conservation of biodiversity through a participatory, data-driven ecoregional assessment process. This document and the accompanying data CD-ROM, represent the results of a two-year process to complete such an assessment for the Carolinian Ecoregion, a 178,000 km2 area that extends from the mouth of the Chesapeake Bay to Cape Canaveral.

It presents the first comprehensive assessment of the region's marine biological diversity. As detailed in the report, the bays and estuaries of the Carolinian Ecoregion continue to hold significant examples of temperate seagrasses, salt and brackish marshes, and native shellfish reefs, even though in some cases they are severely degraded. The deep reefs and live hard-bottom habitat on the continental shelf, while also heavily impacted, also contain important opportunities for conservation.

Based on the best information currently available, the assessment has identified a portfolio of priority areas for conservation and management in the Carolinian Ecoregion. It is essential that the reader understand that the identification of these priority conservation areas makes no presumption about the best strategies for conservation at individual sites. Before identifying conservation strategies, TNC will work with our partners to better understand the present and likely future threats to marine diversity, as well as the biological, socioeconomic, and political circumstances at each site. No single strategy works everywhere, and at any site multiple strategies will be needed.

In other regions, TNC's marine ecoregional assessments have helped spur significant conservation actions. We hope the Carolinian assessment will help shape a new vision for and commitment to the successful conservation and management of coastal and marine ecosystems throughout the region. We hope it will reinforce the many outstanding conservation activities already under way in the region, as well as provide an impetus for new ones.

The Nature Conservancy plans to use the assessment to guide our own coastal and marine work in the ecoregion - to forge new partnerships and to design new conservation strategies. In response to the priorities and needs identified in this assessment, TNC is developing new marine conservation efforts in the Southeast. We believe the Carolinian assessment, especially when used in combination with other planning products - including TNC's terrestrial and fresh-water assessments, EPA's Southeastern Ecological Framework, and state Comprehensive Wildlife Conservation Strategies - can contribute to integrated conservation action across the region.

–**Bob Bendick**
Southeastern Regional Director
The Nature Conservancy

Executive Summary

The purpose of this assessment of the Carolinian Ecoregion is to bring an enhanced focus to marine conservation and management in the region. To achieve this purpose, three products were developed: a spatial database of the region's biodiversity and the factors that affect it, a decision-support framework to evaluate conservation and management alternatives, and a set of conservation areas that represent the region's biodiversity. The assessment involved many partners in academia, state and federal agencies, and other nongovernmental organizations, as well as staff from all state chapters of The Nature Conservancy (TNC) in the region and TNC's Global Marine Initiative. All the tools, data, and results used in the assessment are available in the accompanying CD-ROM to inform and support partner conservation and management efforts.

The temperate estuaries, bays, and continental shelves of the northern hemisphere are among the most heavily degraded of all the environments on Earth - and the Carolinian Ecoregion is no exception. Recent reports by the Environmental Protection Agency, the Heinz Foundation, and U.S. Commission on Ocean Policy highlight the condition of our coastal systems and offer general recommendations for action. The aim of this assessment is to go one step further by providing more specific information and advice on potential priorities for conservation in this ecoregion.

A systematic regional planning approach was used for this assessment. The basic approach was to: identify objectives, i.e., to represent a full range of the region's biodiversity for conservation; select targets to represent this biodiversity and be the focus of conservation efforts (36 targets were included); identify goals for the amount of the targets required to meet objectives; identify suitability factors likely to affect either the cost of conservation, the viability of targets in any area, or the suitability of a specific area for conservation; develop a spatial database from all the reasonably available regional-scale data on the targets and suitability factors, and select priority conservation areas to achieve the stated goals and objectives.

The site-selection tool MARXAN (www.ecology.uq.edu.au/marxan) was used in the decision-support framework to develop potential sets of conservation areas that met our objectives. The results from MARXAN (Figures 15, 16) were peer-reviewed and modified in workshops with scientists, managers, and conservation practitioners (see Appendix 2) to develop a portfolio of Conservation Areas that met the conservation planning objectives. Experts recommended few major changes to the MARXAN results and primarily identified changes to aggregate selected planning units into more biologically meaningful sites.

The end result was a conservation portfolio that included a total of 41 Conservation Areas (Figure 17) and encompassed 21 percent of the ecoregion. The planning team then worked with additional TNC staff to assess the targets, threats, and opportunities at the 41 Conservation Areas. From this process, 11 Action Areas (Figure 18) were recommended as sites where TNC should first explore opportunities for further contributions to marine conservation. The boundaries depicted in Figures 17 and 18 are rough approximations. It is assumed that more ecologically meaningful boundaries will be identified through site-specific planning and conservation efforts.

The identification of these areas makes no presumption about the best strategies for conservation at individual sites. Before identifying conservation strategies, TNC will work with our partners to better understand the present and likely future threats to marine diversity, as well as the biological, socioeconomic, and political circumstances at each site.

Regional, ecosystem-based management is gaining support around the world as an approach for integrated planning and conservation of nearshore marine environments and resources. While there are many elements to effective ecosystem management, one of the essential requirements is the need to efficiently consider multiple species and their habitats as well as the socioeconomic factors in the region. The Carolinian assessment provides a foundation for partner coalitions or individual agencies to develop an ecosystem management framework. This integrated information provides a greater understanding of the biological diversity of the ecoregion and a clearer picture of the condition of its natural areas and the challenges to their continued survival.

We anticipate that partners will use the three main products provided with the assessment - the data, the decision-support tools, and the Conservation Areas - in different ways to meet their objectives. We look forward to collaborating with them in the pursuit of better conservation and management throughout the ecoregion. We also hope the information will spur additional research and monitoring efforts to strengthen this first generation assessment.

There are promising opportunities for conservation throughout the Carolinian Ecoregion and the Southeastern United States. There also is a compelling need for action. We hope the assessment will help shape a new vision for and commitment to the successful conservation and management of coastal and marine ecosystems throughout the region, as well as reinforce the many outstanding conservation activities already under way.

Introduction

The temperate bays and estuaries and the continental shelves of the northern hemisphere are among the most heavily degraded of all the environments on Earth, and the Carolinian Ecoregion is no exception. Two recent reports by the Environmental Protection Agency (USEPA 2005) and the Heinz Foundation (Heinz 2002) specifically address the state of the nation's coastal zone and find that the condition of coastal ecosystems and species is fair at best. The EPA, in its Second National Coastal Condition Report, found that most of the bays and estuaries of the Southeast were in fair to good condition. But those measures most closely related to the ecological condition of the region's biodiversity were worse than any other measure. Overall, the habitat and benthic index measures were rated fair.

There have, in fact, been massive losses in coastal habitat over the last two centuries throughout the Southeast and those losses continue today. Some 3.5 million hectares of coastal wetlands - 37 percent - are estimated to have been lost in North Carolina, South Carolina, and Georgia from the 1780s to the 1980s (Dahl 1990). Although the rate of loss has been reduced, nearly 1,000 hectares of coastal wetlands were still lost in the last decade (EPA 2005).

Native oysters are not just highly threatened, they are functionally extinct in many areas. Oyster populations in North Carolina have been reduced to less than 10 percent of their historic levels (Street et al. 2004). In South Carolina, more than 30 percent of the state's shellfish waters were closed to harvest in 2003 due to water quality issues or their proximity to marinas or other marine uses (Coen 2004). Declining water quality continues to cause concerns in every state and may be a harbinger of the declining quality of estuarine waters throughout the region. On the continental shelf, there have been severe losses in overall productivity; the size and abundance of top predators have fallen precipitously (Myers and Worm 2003).

Yet there is also cause for optimism: the Carolinian Ecoregion still contains remarkable diversity and productivity. There are still areas with extensive marsh and seagrass ecosystems that support great biodiversity and substantial recreational and commercial fisheries. There are large concentrations of coastal fishes and other estuarine-dependent species using the nearshore zone. The region contains 400,000 hectares of potential shellfish habitat. Atlantic and shortnose sturgeon are thought to use virtually all of the region's estuaries to spawn. American shad, Atlantic menhaden, bluefish, striped bass, and black sea bass are just a few of the many resident or migratory species of fish that use these nearshore ecosystems heavily, as do many species of marine mammals. Loggerhead, green, and leatherback turtles nest on the region's beaches. Piping plovers, American oystercatchers, and many other species of shorebirds and colonial water birds nest or winter on the beaches, sand flats, marshes, and swamps.

Over the past few years, there has been increased attention worldwide focused on the declining state of our coasts and oceans, the loss of vital ecological services, and the lack of coordinated management to keep pace with these changes. For example, the recently issued report of the U.S. Commission on Ocean Policy (USCOP 2004) scrutinized the declining condition of our bays, estuaries, and ocean waters. The Commission delineated the many threats to the health of these systems and concluded that appropriate management actions to ameliorate these threats are hindered by a failure to consider the value of the entire marine ecosystem. The Commission called in particular for better regional ecosystem-based management that recognizes the connections within and among ecosystems and their relation to human needs and services.

While the EPA, Heinz, and USCOP reports highlight the condition of our coastal systems and offer general recommendations for action, they do not provide specific information, decision support tools, or advice on potential priorities for the Southeast. The aim of this assessment was to help bridge that gap and to bring an enhanced regional focus to marine conservation and management. To achieve this, a spatial database was compiled on the species and ecosystems of the region and the factors likely to affect them; a decision-support framework was developed to assist in the examination of conservation and management alternatives in workshops; and a set of priority areas that fully and efficiently represent the region's biological diversity was selected. The assessment involved many partners in academia, state and federal agencies, and other non-governmental organizations, as well as staff from all TNC state chapters in the region and TNC's Global Marine Initiative. All the assessment tools and results are readily available to partners to inform and support their own conservation and management efforts.

A systematic regional planning approach was used for the assessment. Scientists, agencies, and private organizations are increasingly using systematic approaches to identify where and how to allocate conservation efforts, particularly at the regional level (e.g., Possingham et al. 1999; Day and Roff 2000; Leslie et al. 2002; Airame et al. 2003). The Nature Conservancy has been among those at the forefront in the development of new approaches for systematic regional planning (e.g., Beck and Odaya 2001; Groves et al. 2002; Groves 2003; Beck 2003, Ferdaña in press).

The basic approach to systematic planning is to: Identify objectives, which in the Carolinian assessment was to identify and represent a full range of the region's biodiversity for conservation. Select targets (e.g., species and ecosystems) to represent this biodiversity and be the focus of conservation efforts. Identify goals for the amount (abundance, area, distribution) of the targets required to meet objectives. Identify suitability factors (e.g., human population density, shipping lanes) likely to affect either the cost of conservation, the viability of targets in any area, or the suitability of a specific area for conservation. Develop a spatial database from all the reasonably available regional-scale data on the targets and suitability factors. Establish stratification and planning units in which the distribution of targets and suitability factors are tracked. Select priority conservation areas to achieve the stated goals and objectives. Site-selection tools are commonly used to help process this information towards optimal solutions that meet objectives. In this assessment, the software program MARXAN (Ball and Possingham 2000) was used to arrive at multiple potential solutions. The results from MARXAN were peer-reviewed and modified in workshops with scientists, managers, and conservation practitioners to develop a final portfolio of conservation areas.

The results of the assessment make clear that there are promising opportunities for conservation throughout the ecoregion. There also is a compelling need for action. While effective ecosystem-based management has many elements, one of the most important is the need to consider simultaneously the conservation of multiple species and their habitats and the multiple human factors that affect them. The data and tools developed through the Carolinian assessment provide one important perspective for moving towards an ecosystem-based management approach. The assessment is intended to serve as a comprehensive guide and as a mechanism to bring together decision-makers and stakeholders from all sectors to help shape a brighter future.

Description of the Ecoregion[1]

The Carolinian Ecoregion extends from the mouth of the Chesapeake Bay in Virginia south to Cape Canaveral in Florida. It includes the temperate bays, estuaries, and coastal marshes of five states and the waters, deep reefs, and sand plains of the continental shelf. Its eastward or seaward boundary is the shelf edge at the 200-meter isobath; its western boundary is the zone along the coastal plain where salt-tolerant plants and ecological communities are replaced on the landscape by predominantly fresh-water species. The ecoregion is characterized by a broad, shallow shelf platform, extensive sandy barrier islands and beaches, many productive estuaries, vast coastal marshes, and major piedmont and coastal plain rivers that terminate at the coastal margin.

Rivers have a substantial influence on the characteristics of the ecoregion, carrying fresh water, sediments, and nutrients that strongly affect many of the ecological processes in the nearshore and estuarine waters. Another major influence is the presence of the warm northward-flowing Gulf Stream, which has its nominal western boundary near the edge of the continental shelf. As the Gulf Stream pours northward toward the Outer Banks and Cape Hatteras, it sends small eddies and upwellings across the shelf. One major upwelling is located just to the north of Cape Canaveral. Another, much larger and stronger, is the Charleston Gyre, which generates a consistent surge of nutrient-rich deep waters that are the main steady source of nutrients in the South Atlantic Bight and contribute significantly to primary and secondary production in the ecoregion (SAFMC 1998).

The Carolinian Ecoregion is contiguous with the terrestrial ecoregions of the Mid-Atlantic, South Atlantic, and Upper Florida coastal plains. This broad, sandy coastal margin is bordered by narrow strands of barrier islands and expansive salt and brackish marshes interspersed with numerous rivers and tidal inlets. The marshes occur in low-lying areas between the mainland and the barrier islands and are at their widest (12 kilometers) from Beaufort, South Carolina, to Brunswick, Georgia (Dame et al. 2000). More than 90 percent of the commercially and recreationally sought fish in the region are composed of estuarine-dependent species, and the marshes provide them with essential food, structure, and refuge from predators. The marshes also regulate the amount of fresh water, nutrient, and sediment inputs into the estuaries and play an important role in estuarine water quality. The position of salt marshes along estuarine margins and their dense stands of persistent plants also make them essential for stabilizing shorelines and for storing floodwaters during coastal storms.

Although nowhere near as extensive as the marshes, seagrasses are yet another important ecosystem in the ecoregion. Eight species of seagrasses grow in the estuaries of northern North Carolina and Florida (Ferguson and Wood 1994; Hanlon and Voss 1975). From southern North Carolina through south Georgia, highly turbid fresh-water discharges, suspended sediments, and a large tidal amplitude (up to three meters) combine to prevent the permanent establishment of most seagrasses. Where they occur, seagrasses are among the most productive ecosystems in the world (Duarte 2002; Green and Short 2003) and one of the most important ecosystems in the ecoregion.

Major rivers with discharges ranging from 1,000 to 15,000 cubic feet per second pour into the estuaries and nearshore ocean. These rivers include the Roanoke, Tar, Neuse, and Cape Fear in North Carolina; the Pee Dee and Cooper-Santee in South Carolina; the Savannah and Altamaha in Georgia; and the St. John's in Florida. Many smaller coastal plain rivers such as the New River in North Carolina and the Satilla in Georgia have smaller flows but still have a significant influence on estuarine processes and conditions (Dame et al. 2000).

Although the continental shelf is mostly a broad, sandy plain, there are many important "islands" of live hard bottom offshore, ranging from rocky areas with little vertical relief that support patchy communities of sponge and corals to areas of high-relief outcroppings with abundant invertebrate growth. These hard-bottom sites support hundreds of species of plants, invertebrates, and reef fishes such as groupers, grunts, snappers, sea bass, trigger fish, tilefish, blennies, gobies, sharks, and eels (SEAMAP-SA 2001).

Threaded across the lands and waters of the ecoregion are four National Seashores (Cape Hatteras, Cape Lookout, Cumberland Island and Cape Canaveral), 21 National Wildlife Refuges, two National Estuary Programs (Albemarle-Pamlico Sound and Indian River Lagoon), two National Marine Sanctuaries (USS Monitor and Gray's Reef), and five National Estuarine Research Reserves (North Carolina Reserve; North Inlet, SC; ACE Basin, SC; Sapelo Island, GA; Guana Tolomato Matanzas Reserve, FL).

[1] In this assessment, the terms province, ecoregion, and region are essentially synonymous. Many partners use different terms to identify these areas (provinces, regions, ecoregions) and the process of database development and planning within them (regional planning, ecoregional assessments).

CONSERVATION TARGETS AND SOURCES OF DATA

The objective of this assessment was to identify and represent a full range of the region's diversity for conservation. The first step in regional assessments is to select conservation targets. These targets are the elements of biological diversity - such as species and ecosystems - that are the focus of the assessment and future conservation and management efforts. Because it is impossible to identify or plan for all elements of biological diversity (e.g., the thousands of species in the Carolinian Ecoregion), a subset of targets was selected to best represent the diversity of the ecoregion (Groves et al. 2002). These targets were defined based on biological features (e.g., species, ecosystems) and physical features (e.g., bathymetry, sediments).

Marine ecosystems were the first targets of focus. This approach presumes that the conservation of a representation of all the ecosystems (e.g., seagrass, salt marsh, offshore coral reefs, and hard bottom areas) will also conserve a representation of the diversity of species found in these ecosystems (Noss 1987, Hunter et al. 1988). Nearshore, it is appropriate to focus on and identify as targets the well-known, biologically defined entities such as shellfish and seagrass ecosystems.

To add to the characterization of nearshore ecosystems, targets for shoreline types were also added. These shoreline types were included as surrogates for ecosystems along shores where specific spatial data were sometimes lacking. The Environmental Sensitivity Index developed by NOAA (NOAA ESI) included information on shorelines types for the entire ecoregion.

In offshore areas, much less information is available on diversity overall and on potential ecosystem types in particular. Hard bottom and coral reef areas were included as specific ecosystem targets, because these areas often have characteristic and diverse assemblages.

In the absence of other biological data in offshore areas, geophysical data (e.g., depth, bottom complexity) were used as surrogates to identify areas that were likely to represent different types of benthic habitats and associated assemblages of plants and animals. In many marine systems, there are strong positive correlations between structural complexity and species diversity and abundance (Beck 2000; Yoklavich et al. 2000; Hixon et al. 1991; Field et al. 2002; Starr 1998 Williams and Ralston 2002). Areas of high structural complexity were identified at different depths on the assumption that these areas would have different and diverse assemblages. While other areas are also likely to have different and diverse assemblages (e.g., deep, sandy or muddy bottoms) there was insufficient information to make predictions on other likely surrogates for offshore habitats or ecosystems. The development of better "benthic models" is a current area of research by many scientists, including several at TNC.

Some individual species and areas with aggregations of species were also included as targets. Not all biodiversity can be conserved through a focus at the ecosystem level. Elements least likely to be represented by such a focus are endangered and imperiled species. Many of these species require individual attention because management of their habitats alone is necessary but insufficient for their conservation. Indeed some species are declining faster than their habitats. It is also important to identify target species that are vital to the structure and function of ecosystems, because they may be keystone species or ecosystem engineers that are crucial for creating or structuring ecosystems (Lawton 1994; Lenihan 1999). A limited number of species were selected that met these requirements, including Eastern oyster; shortnose sturgeon; loggerhead, green, and leatherback turtle; piping plover; American oystercatcher, and right whale.

Offshore, there was often little information available on areas that might be critical for particular species or where species might be aggregating except for where the South Atlantic Fishery Management Council has identified some Habitat Areas of Particular Concern (HAPCs). These HAPCs were included as targets because they were likely to represent critical habitat for many species. The HAPC designation was based on the following criteria: rarity; importance of the ecological functions provided by the habitat; the extent to which the habitat is sensitive to human-induced environmental degradation; and whether and to what extent development activities are or will create stresses on the habitat (SAFMC 1998). While the focus of the assessment was on the conservation of biodiversity rather than fishery enhancement, the HAPCs are likely to represent critical habitat and aggregation areas in general for many species.

A total of 36 targets were included in the assessment (Table 1, Figures 3-11). At various stages in the target identification and data collection process, team members and consulting scientists evaluated the target list and the quality of data. Scientists also were asked to evaluate assumptions about sites, systems, stresses, and important ecological processes in the ecoregion.

The primary source of information for each of the targets has been provided below. Information on why specific targets were chosen was provided above. The targets are ordered to represents major ecosystem-type targets, surrogates for ecosystem targets (such as shoreline types), species' targets, and surrogates for aggregations or habitats critical for multiple species (HAPCs). In some cases, detailed datasets were available (e.g., site-specific data on wetland ecosystems), but to ensure relative comparability in the information used to assess diversity across the ecoregion, regional datasets generally were required for (or comparable information had to be available for large portions of the region).

Seagrass Ecosystems - Information on seagrass distribution was provided by NOAA-National Marine Fisheries Service. Seagrass beds occur only in the extreme northern and southern reaches of the ecoregion. Seagrasses are not present in Georgia and South Carolina where fresh-water inflow, high turbidity, and tidal amplitudes combine to prevent their occurrence. Seagrass maps in North Carolina are based on 1991-92 aerial photography conducted for the Albemarle-Pamlico National Estuary Program. Much of the work on seagrasses from the Florida portion of the ecoregion was done through the Indian River Lagoon National Estuary Program. More recent and more detailed data are available for this area based on distribution analyses conducted as recently as 1999.

Shellfish Ecosystems - The only regional-scale data on shellfish were the Environmental Protection Agency's maps showing Southeastern Atlantic waters classified as supporting shellfish. However, the EPA classification system is based on water quality parameters rather than actual distributions and includes large areas where oysters and other bivalves may have never occurred. As a result, data on shellfish were obtained from individual state agencies, and due to significant differences in the standards used for shellfish mapping from state to state, the data may contain inconsistencies. This target and the datasets primarily represent oyster reefs, but clams are also included.

Wetland Ecosystems - The best national classification for wetland marine habitats was developed by the U.S. Fish and Wildlife Service's National Wetlands Inventory (Cowardin et al. 1979). In some instances, more detailed classifications and more recent distribution data have been compiled at the state level, but at an ecoregional scale, the NWI classification and distribution data are the most consistent. The NWI system categorizes marshes and other wetland types according to salinity, position in the tidal regime, substrates and other abiotic features, vegetation types, and other factors. Information was extracted for seven major types of wetland ecosystems: (i) regularly flooded salt marshes, (ii) irregularly flooded salt-brackish marshes, (iii) intertidal scrub/shrublands, (iv) salt-brackish marshes with variable flood regimes, (v) tidal fresh marshes, (vi) fresh marshes, and (vii) forested wetlands.

Reefs and Hard Bottom Areas - Information on the location of corals and other hard-bottom reef habitat assemblages was obtained from the Bottom Mapping Work Group of the Southeast Area Monitoring and Assessment Program (SEAMAP). The project was organized under the auspices of the Atlantic States Marine Fisheries Commission and was intended primarily to document the distribution of habitats important for many of the finfish species that are harvested commercially and recreationally in the region. These habitats can include a variety of bottom types, ranging from areas with little or no vertical relief that support patchy communities of sponges and corals to areas of high-relief rocky outcroppings and abundant invertebrate growth. For examples, the Gray's Reef National Marine Sanctuary contains some of the most outstanding examples of northern hard bottom in the ecoregion. Composed of a series of rocky ridges, the sanctuary covers just 57 km2; more than 66 species of reef fish have been identified in its varied habitats. Scientists compiled more than 65,000 data records to code bottom types across the ecoregion. Still, the actual extent of reefs and hard bottom is probably underestimated. Because these areas are such an important component of the ecoregion's diversity, more work is needed to fully characterize their distribution and the conservation issues surrounding them (SEAMAP-SA 2001).

Shoreline Types - Data from the NOAA Environmental Sensitivity Index were used to map shoreline types. The NOAA ESI was developed as part of the federal government's oil-spill contingency planning and response program and incorporates the physical and biological characteristics of the shoreline environment. Information was extracted on substrate type and grain size for four shoreline types: (i) mixed sand and gravel beaches, (ii) gravel-shell beaches,

(iii) fine sand beaches, and (iv) coarse sand beaches. Three other shoreline types - sheltered tidal flats, exposed tidal flats and exposed scarps - were mapped on a more limited basis. In some instances ESI shoreline types overlapped National Wetland Inventory (NWI) types (e.g., a shoreline classified as a tidal flat in ESI bordered an area classified as salt marsh habitat in the NWI). In such cases, only the NWI data were used in analyses to avoid duplicating information at particular sites.

Areas of High Structural Complexity - To identify areas that were likely to have greater structural complexity, the Duke University Geographic Analysis Unit developed a GIS model using ecoregional bathymetric data and geophysical/topographic features. Bathymetric topography was evaluated for local variations in depth and aspect in order to assess areas with high levels of structural variability. The continental shelf was divided into two depth classes: 0-50 meters and 50-200 meters to identify areas of high structural complexity as distinct targets in these two depth classes. It was assumed that there would likely be differences in assemblages of species in at least these different depth classes; it is likely that there may be even further stratification by depth in assemblages.

Sea Turtle Nesting Beaches - The biological resources component of the NOAA ESI was used to identify the location of beaches used by nesting sea turtles and to rank particular reaches of shoreline according to the concentration of nesting turtles present over time. Turtle species included in the ESI were loggerhead, leatherback, and green. Several states had information available at a finer resolution for certain species, but the ESI provided the level of detail and consistency needed at an ecoregional scale. To test the relative accuracy of the ESI, distribution and concentration data for South Carolina beaches from the ESI were compared with 17 years of data compiled by the South Carolina Department of Natural Resources on loggerhead nesting beaches. In every instance, shoreline reaches identified by the ESI as significant sea turtle areas were also identified as such by SCDNR (Hopkins-Murphy 2001). It was assumed that the ESI data would also provide a reasonable representation of nesting areas throughout the rest of the ecoregion.

Right Whale Calving Grounds - Critical habitat for the northern right whale was incorporated into the analysis by using boundaries established by the National Marine Fisheries Service to designate and protect the only known right whale calving grounds in the Northwest Atlantic. The area we used is that established under the federal Mandatory Ship Reporting System; it is the area in which large commercial ships are required to report their movements from November 15 to April 15 when adults and calves are present. The area encompasses nearly 500,000 hectares of shallow, nearshore waters between the Altamaha River and Sebastian Inlet, south of Cape Canaveral.

Shortnose Sturgeon - Comprehensive information on specific spawning sites and population dynamics of shortnose sturgeon was not available; little data exist on this anadromous fish and uncertainty surrounds its present status. Data were pulled together from the National Marine Fisheries Service, U.S. Fish and Wildlife Service, state agencies, individual scientists, and other sources to develop a sense of the sturgeon's range, which includes most major river systems along the eastern seaboard of the United States. Within the Carolinian Ecoregion shortnose sturgeon have been recorded in the St. John's River in Florida; the Altamaha, Ogeechee, and Savannah Rivers in Georgia; the ACE Basin, the rivers that empty into Winyah Bay, and the Santee/Cooper River complex in South Carolina; and the Cape Fear, Neuse, and possibly the Roanoke River in North Carolina (NMFS 1998). Because data on specific spawning sites were not available, all these rivers were included as potential spawning areas with the understanding that this species would require considerably more investigation in future versions of the assessment. It was further assumed that areas identified as important habitat for the shortnose sturgeon could serve as a surrogate for areas important for other anadromous species as well (for which data were often even more limited).

Shorebirds and Waterbirds -Information on birds or bird aggregations was collected from a variety of sources.

American Oystercatcher - American oystercatchers are considered a species of concern by the U.S. Fish and Wildlife Service's South Atlantic Migratory Bird Initiative. We used data on oystercatcher roosting sites collected in 2002 by researchers at the Manomet Center for Conservation Sciences in Manomet, Massachusetts. The roost sites also indicate the general location of oystercatcher foraging areas since the birds tend to roost near their foraging grounds if possible (Brown 2005).

Piping Plover - Relatively detailed maps showing the wintering habitat of the federally listed piping plover were obtained from the July 10, 2001, issue of the Federal Register, published as part of the Fish and Wildlife Service's effort to declare areas as critical habitat for plover populations. Plover wintering habitat generally consists of intertidal beaches and flats (between annual low tide and annual high tide) and associated dune systems and flats above annual high tide, and may include beaches, mud flats, sand flats, algal flats, and areas where breaks in dunes result in inlets being formed (USFWS 2001).

Colonial Nesting Water Birds - Because a generalized trend over time was more robust than an individual observation, we used several years of data from the national Waterbird Monitoring Partnership database at the USGS Patuxent Wildlife Research Center to map the breeding sites for eight species of colonial waterbirds: (i) yellow-crowned night herons, (ii) wood storks, (iii) little blue herons, (iv) green herons, (v) common terns, (vi) black skimmers, (vii) black-crowned night herons, and (viii) reddish egrets. These eight species have all been listed by the Southeast Waterbird Conservation Plan as species of concern and in need of immediate management. Black skimmers and common terns, like oystercatchers and piping plovers, tend to nest on beaches and sand flats; the other six species tend to nest in forested or brushy wetlands.

Habitat Areas of Particular Concern - The South Atlantic Fishery Management Council is currently developing comprehensive data on the location of critical spawning and breeding sites for many commercially valuable finfish species. Some Habitat Areas of Particular Concern (HAPCs) have already been identified.

Charleston Bump and Gyre Complex - The topographic irregularity southeast of Charleston known as the Charleston Bump is an area of productive seafloor that rises abruptly from 700 to 300 meters within the short distance of about 20 kilometers. The cyclonic Charleston Gyre is a permanent oceanographic feature of the South Atlantic Bight caused by the reflection of rapidly moving Gulf Stream waters by the Charleston Bump. The gyre produces a large area of upwelling of nutrients from depths of 450 meters to less than 50 meters. This is the main steady source of nutrients near the shelf break within the entire South Atlantic Bight and contributes significantly to primary and secondary production in the ecoregion. The gyre is considered an essential nursery habitat for offshore fish species with pelagic stages. It also plays a role in retention of fish eggs and larvae and their transport onshore.

The Point, Ten Fathom Ledge, and Big Rock - Off Cape Hatteras, the confluence of the Gulf Stream with as many as three other water masses creates a dynamic and highly productive environment known as The Point (or Hatteras Corner). Adults of many highly migratory species congregate in this area, and the diversity of larval fishes found here is described as astounding. Ten Fathom Ledge encompasses numerous patch reefs of coral-algal-sponge growth on rock outcroppings over 136 square miles of ocean floor, beginning along the southern edge of Cape Lookout Shoals. Big Rock encompasses 36 square miles of deep drowned reef around the 50-100 meter isobath some 36 miles south of Cape Lookout. Unique bottom topography at both sites produces oases of productive bottom relief with diverse epifaunal and algal communities surrounded by a generally monotonous and relatively unproductive sand bottom. Approximately 150 species of reef-associated species have been documented from Ten Fathom Ledge and Big Rock.

CONSERVATION GOALS

Conservation goals were identified to define the amount and spatial distribution needed to provide conservation for a full representation of the diversity in the region. These goals were used to help set priorities on where to focus efforts; they were not intended to indicate that some portion of the targets were not important for conservation. Conservation goals have two components: a "representation goal" that specifies the number or amount of a target and a "stratification component" that guarantees that the target will be represented throughout the ecoregion.

There is no specific formula to determine how much habitat or how many populations are required to conserve any particular target. However, representation goals should be based on some measure of abundance and distribution (Groves et al. 2000; Groves 2003). Generally, goals are set in the 30 to 40 percent range for terrestrial ecosystems and communities with the assumption that this will capture 80 to 90 percent of species (Groves 2003). In the marine environment, lower goals may be more appropriate since the areas around conserved sites may continue to support species and ecosystems to a greater extent than in terrestrial environments (Beck 2003). It is also important to consider historical distributions and to set higher goals for rare or imperiled species or ecosystems that have been substantially reduced in distribution or abundance.

In the Carolinian Ecoregion, all representation goals were set at 30 percent of their current distributions or higher, because many of the targets have been substantially reduced in abundance or degraded in terms of function or quality. For the federally listed piping plover, a goal was set for 50 percent goal of its wintering habitat. For the reddish egret, a 100 percent goal was set, because there is only one recorded egret rookery in the ecoregion. For four particular shoreline targets for which relatively few records were available from the ESI shoreline characterization index, the goal was raised to 40 percent; these were sheltered tidal flats, sheltered tidal flats with oysters, exposed tidal flat, and exposed scarp with clay. For the HAPCs, a 30 percent goal was set for the very large Charleston Bump and Gyre Complex, but goals of 100 percent were used for the other three HAPCs because they were relatively limited in size and confined to specific locations. (For a complete list of goals see Table 2.)

The current distribution of some targets already may be insufficient for their continued persistence. In some instances - particularly with regard to shellfish ecosystems- restoration of populations or habitats will be required to meet goals for conservation. The goals for shellfish ecosystems were set at 30 percent of their potential distributions (i.e., classified as supporting shellfish by EPA).

STRATIFICATION AND PLANNING UNITS

For planning purposes, the ecoregion was divided into stratification (or subregional) units to ensure adequate representation and conservation of diversity throughout the region. Through stratification, we are primarily trying to represent unknown biodiversity (e.g., possible genetic variation in species or community-level variation within ecosystems). In addition, stratification helps to ensure that conservation areas are distributed across the ecoregion and that local catastrophes (e.g., hurricanes) will not impact all the conservation areas identified for a target (i.e., risk spreading).

Six subregions were identified and conservation goals had to be met not only overall but in every sub-region in which the target occurred. Our first step was to establish northern, central, and southern stratification units. Ecologically, the region's estuaries can be classified into three broad types: the extensive, poorly flushed sounds of southeastern Virginia and North Carolina, the well-flushed bar-built and riverine estuaries of South Carolina and Georgia, and the poorly flushed bar-built estuaries of northeastern Florida (Dame et al. 2000). We used this characteristic as the primary element on which to base the subregions. These stratification units follow well understood transition zones where different assemblages of species were found. We also divided the ecoregion into inshore and offshore zones corresponding to the 50m isobath to account for variation in diversity across this gradient. The following stratification units were identified: Northern Inshore, Northern Offshore, Central Inshore, Central Offshore, Southern Inshore, and Southern Offshore (Figure 12).

The ecoregion was divided into 11,903 hexagonal "planning units," each representing 1,500 hectares. Planning units are the smallest elements in which targets and the suitability factors are tracked. Attributing target and cost information to a finite set of planning units makes subsequent decisions more manageable and reduces the relative complexity of the assessment process. Hexagons were used for the planning units (rather than squares or rectangles) because their shape allows for more natural-appearing clumps based on the amount of boundary (six sides) shared among individual planning units.

SUITABILITY INDEX

In addition to identifying conservation targets and goals, a suitability index was developed to help identify factors that were likely to have adverse affects on conservation targets and to help steer the selection of conservation areas away from places likely to be affected by human use. For instance, an area that has been extensively developed or contains numerous pollution sources might be less suitable for biodiversity in general than an area that has been less developed. It may be more costly to achieve conservation in such areas as well.

Spatial data were compiled for 10 types of suitability or "cost" factors (Table 3, Figure 13) and a suitability index (Figure 14) was generated by tallying the total number of impacts within any given planning unit. The cost factors used were:

- Mean population change, 1990-2000.
- Housing density.
- Road density.
- Major port facilities.

• Major shipping lanes.
• Dredged shipping channels.
• Hardened shorelines.
• EPA Superfund sites.
• Permitted pollution discharge sites.
• Dredged material disposal site.

Each impact was given a certain number of suitability points based on its potential to affect target integrity, its potential for reversibility, and the extent to which it was present in a planning unit. In addition, since the selection of any area for conservation or management entails some cost, each planning unit was given a base cost of 35 points before adding the other costs identified above. This was done to assure that planners recognized the importance of spatial efficiency and the potential costs associated with including more areas for conservation and management.

In this analysis, we focused on evaluating the relative impact of anthropogenic development at specific locations. We did not include the accumulation of "upstream" effects within watersheds. The suitability index was reviewed by natural resource conservation experts from the region and refined based on feedback provided in workshops.

SELECTING CONSERVATION AREAS

The primary purpose of the assessment was to provide an ecoregional context in which to make good decisions for lasting conservation and effective natural resource management. TNC has developed a general framework to support decisions. This decision support framework includes the identification of clear targets, goals, suitability and other factors as well as justifications for the quantitative values assigned to these factors. We also use tools that allow us easily to alter these factors and their values to assess how these changes might affect decisions. This framework provides a transparent and dynamic approach for decision support.

One major element of the assessment was to select a single, efficient, yet comprehensive network of priority conservation areas that, if effectively conserved, would best sustain the biological diversity of the region. The selection process had to ensure that conservation goals for the representation and distribution of all targets were met as efficiently as possible, with total cost factors and total area minimized. This network - the conservation portfolio - would then become the focus of more detailed planning and more intensive conservation efforts.

The site-selection program MARXAN (v.1.8.2) (Ball and Possingham 2000), was used in the decision-support framework to provide a dynamic platform on which targets, goals, suitability, and other factors could be evaluated under different scenarios. The basic inputs to MARXAN included:

• the amount and distribution of conservation targets in each planning unit.
• a specific conservation goal for each target.
• the cost factors for each planning unit.
• planning unit boundaries.

MARXAN employs a statistical sampling method known as "simulated annealing" that compares many different sets of potential conservation areas against a measurable objective and determines which one achieves its goals most efficiently.

In addition to the targets, goals, and suitability factors, there are several settings that must be identified before running a MARXAN scenario. These include the number of times the program will run through the simulated annealing process, the number of iterations per run, the penalty factor levied for not meeting stated conservation goals, and the boundary length modifier (BLM), a factor that determines how much weight will be placed on retaining spatial contiguity within the portfolio. The penalty factor determines the significance placed on not reaching the representation goal for the individual targets. A target that has not reached its representation goal is assessed a portion of this penalty value based on the proportion of shortfall. The BLM affects the amount of dispersion as opposed to clumping of planning units into conservation areas. Smaller BLMs produce little or no clumping of planning units and result in smaller, more highly dispersed areas and a lower number of planning units selected. High BLMs generally produce fewer, larger areas but with a higher total number of planning units selected.

All the analyses presented below were based on 50 repeat runs of the simulated annealing process including one million individual iterations per run with a penalty factor of 1000 and a BLM of 0.05. Of these factors, the level of BLM had the greatest effect on the final results. Analyses with different BLM levels were compared in workshops and a BLM of 0.05 appeared to provide an appropriate balance between spatial efficiency and biological relevance in the size and spread of areas selected. Results using different BLM levels are provided on the accompanying CD-ROM.

Results

DELINEATION OF CONSERVATION AREAS

MARXAN produced two types of output that were used to guide the development of a conservation portfolio: a "best solution" and a "summed solution." The "best solution" is the set of planning units that best meets the conservation goals for all targets at the minimum cost. The best solution for this assessment (Figure 15) resulted in a set of 78 sites that included 2,603 planning units for a total area of slightly more than 3.9 million hectares - or 21.8 percent of the ecoregion. In truth, there is no single best solution since it is mathematically impossible to obtain a truly optimal output and since certain outputs may be statistically indistinguishable from others. The best solution met the conservation goals for all 36 targets and exceeded goals for many (Table 4). Thirteen targets were over-represented, which we identified as occurring when the amount of a target in the selected planning units exceeded its goals by greater than 130 percent.

The "summed solution" (Figure 16) represents how many times each of the ecoregion's 11,903 planning units was selected in the repeated runs of MARXAN. This can be interpreted as one measure of any one planning unit's biological importance - and potential conservation value - relative to less frequently selected units. The summed solution can be used to identify core areas that are most likely to be needed for inclusion in any final set of conservation areas.

These model results were reviewed in workshops and working groups with experts and TNC staff (see Appendix 2) to arrive at a final portfolio of Conservation Areas (Figure 17). The final conservation portfolio includes a total of 41 Conservation Areas (Figure 17). The portfolio encompasses 2,510 planning units or 3.77 million hectares, which is about 21 percent of the ecoregion.

Experts recommended few substantive changes to the MARXAN results per se. Most of the changes represented the aggregation or clustering of selected planning units into more biologically meaningful sites. However, there were a few significant changes in the amount of targets captured between the MARXAN best solution (Figure 15) and the final set of Conservation Areas (Figure 17). For instance, the best solution captured 25,406 hectares of seagrass beds, while the final portfolio captures 36,266 hectares. Shellfish habitat increased from 131,916 hectares in the best solution to 206,769 in the final portfolio.

By comparing the summed solution (Figure 16) to the final portfolio (Figure 17), it was also clear that the final portfolio incorporated most of the planning units that were selected in multiple MARXAN runs. For instance, 204 planning units were selected in at least 90 percent of the MARXAN runs, and all but three of these were included in the final portfolio. Two hundred and forty-seven units were chosen in at least 80 percent of the MARXAN runs, and all but eight were included in the final portfolio.

The Conservation Area boundaries depicted in Figure 17 represent only rough approximations of specific sites. At a regional level - and using regional-scale data - only very general boundaries were established. As additional data become available - and as we work with partners to design detailed conservation strategies - the boundaries of these areas will very likely be adjusted. In some instances, some areas may be clumped together to form larger sites.

PRELIMINARY THREATS REVIEW

The estuaries and shallow coastal habitats of the Carolinian Ecoregion are rich and productive because they receive inputs from terrestrial, fresh-water, and marine sources. They are also affected by stresses from these same environments.

A stress is a factor that impairs or degrades the size, condition, or landscape context of a conservation target and therefore reduces its viability. Together, the stress and its source (i.e., sedimentation from agricultural practices) are called a threat (Groves et al. 2000).

A comprehensive threats analysis has not been conducted for the ecoregion. Such an analysis will be needed before appropriate conservation strategies can be developed. However, based on available data, past experience, and expert opinion, it was possible to prepare a preliminary list of the most pervasive threats and to begin to think about them in relation to each priority conservation area. More detailed assessments will be completed on a site-by-site basis during conservation area planning. A summary of threats considered present throughout the ecoregion follows.

Nutrification - Nutrification is an oversupply of nutrients into a natural system, particularly nitrogen and phosphorous. Nutrification can arise from many sources although in most instances it arises principally from agriculture, with secondary inputs from municipal sources. Nutrification can have pervasive ecological effects on shallow coastal and estuarine systems. These effects include reduced water clarity, loss of aquatic habitat, algal blooms (toxic and non-toxic), and a decline in dissolved oxygen (hypoxia and anoxia). Nutrification generally favors the growth of single-celled and small algae at the expense of macrophytes such as seagrass and marsh species. When waters become hypoxic or anoxic few animals that require oxygen can survive.

Altered fresh-water hydrologic regime, including changes in fresh-water inflows - Alterations in fresh-water flow change the basic characteristics of estuaries by altering the dynamic exchange between fresh and salt water. The natural flow patterns of rivers and streams are important mechanisms for maintaining adequate oxygen, salinity, and temperature levels and for dissipating wastes. Changes in the natural flow regime (volume and timing) affect important ecological processes that control the abundance of many target species and habitats. Sources of this stress include dams, levees, channelization, and excessive surface and groundwater withdrawal. Many nearshore species are euryhaline, i.e., tolerant of a wide range of salinities. Nonetheless, long-term changes in the mean and variability of salinity still affect the distribution and abundance of these species.

Shoreline hardening - Changes in the flow of salt water principally affect tidal and wave energy and sediment transport. In places where shorelines are being armored by seawalls and similar structures, wave energy is reflected, leading to erosion of adjacent soft sediment habitats (e.g., marshes). Jetties and groins affect the long-shore transport of sediments, which changes the movements of barrier islands and results in new patterns of sediment accretion in some areas and sediment loss in others.

Light attenuation - The distribution of submerged macrophytes (seagrasses and fresh-water grasses) is closely tied to light availability. If light levels are reduced, the blade density of a grass bed declines and eventually the entire grass bed can be lost. Blooms of algae associated with brown tides are an important source of this stress. The source of these brown tides is an open question, but it is well known that they thrive when there are excess nutrients. Incompatible coastal development can increase water turbidity through indirect runoff across hardened surfaces and direct discharges from municipal wastewater. Trawling and heavy boat traffic in shallow water can suspend bottom sediments, which also reduces light availability. On a smaller scale, docks can attenuate the light that reaches the grasses underneath and around them.

Direct target destruction - There are many sources that contribute to the direct destruction of targets, including incompatible coastal development, dredging, inappropriate recreational use, invasive species, and overfishing. Incompatible coastal development (e.g., poorly designed homes, ports, docks, seawalls, golf courses, and marinas) has major direct impacts on habitats and species. This development also contributes to indirect target destruction by being a source of some of the other stresses identified in this section (e.g., altered flow regime, sedimentation, light availability, or nutrient source). Dredging also can destroy targets directly and indirectly. Inappropriate recreational use can also be a problem. Propellers of recreational boats are responsible for extensive scarring of seagrass beds. Even scarring from anchors can be a significant problem in places with few seagrasses left. Overfishing can significantly alter population abundance and habitats. Trawl fishing can affect targets directly when they are taken as bycatch (e.g., turtles) and can alter habitats when the trawl scrapes them. The loss of some species, such as oysters, can have system-level effects on water clarity.

Invasive species - There are currently relatively few invasive species known to cause major problems in the ecoregion, although the number is likely to grow. The highly venomous red lionfish (Pterois volitans), native to the South Pacific and Indian oceans and the Red Sea, was first observed off the coast of North Carolina in 2000. Since then, numerous observations have been recorded from South Florida to Long Island. The unexpected arrival of this species in the Atlantic has generated a storm of scientific and public inquiry regarding how it was introduced and its potential impact on area ecosystems. Potential effects could include decreases in prey population abundance, increased competition with other mid-level predators and poisoning of higher level predators that attempt to prey on lionfish (e.g., grouper, shark). Another recent arrival is the green porcelain crab (Petrolisthes armatus), never recorded north of Cape Canaveral before 1994 but now found in abundance as far north as Murrells Inlet, South Carolina

Inflow of toxins, contaminants, and pollutants - Overall the level of these stresses from point sources has decreased, but inputs from non-point sources (e.g., septic systems and stormwater runoff) are on the rise.

Sea level rise - The average rate of sea level rise has ranged from two to four millimeters per year along the Southeastern coastline, or approximately one foot per century (PSMSL 2005). These historic rates are nearly twice the global average, and sea level rise is expected to accelerate in coming decades. Rising seas threaten low-lying coastal plains and barrier islands by increasing and prolonging coastal flooding and erosion. Perhaps the most dramatic threat is the potential submergence of the ecoregion's extensive marsh systems. The influx of salt water will affect species and communities that require brackish to fresh water and that may already be risk from other stresses.

DATA GAPS AND LIMITATIONS

We relied on data for this assessment that made it possible to map conservation targets across the entire ecoregion.. More detailed data are available for some areas within the ecoregion but are probably better suited for site-level conservation planning.

Given these qualifications and reservations, there are a number of data gaps or data limitations that should be considered while using the assessment. Although we do not believe they affect the assessment's integrity, they are sources of uncertainty at the ecoregional scale and could be fruitful topics for additional research.

Connections between nearshore and offshore - Connections between nearshore and offshore environments are represented in some of the priority areas identified in the assessment (e.g., the Sewee-Santee-Winyah Bay Estuarine Complex and the Charleston Bump and Gyre Complex; Pamlico Sound-Outer Banks Estuarine Complex and the Outer Banks Ocean Complex). In general these represent important areas nearshore and offshore. It is well known that there are important connections between nearshore and offshore marine environments in the ecoregion, particularly among species that have juvenile stages nearshore and adult stages offshore. It is equally well known that migration pathways between nearshore and offshore are the least well understood part of the biology and ecology of these species (Beck et al. 2001; Beck et al. 2003; Minello et al. 2003, Gillanders et al. 2003). Some obvious connections occur at key inlets between the oceans and the estuaries (e.g., Oregon Inlet, North Carolina). For planning purposes, we have identified these "connected" sites as separate areas because some of the diversity, threats, and possible strategies are different in the nearshore and offshore environments. At this point the exact connections between these nearshore and offshore sites is a data gap that needs to be filled. However, we do not want to lose sight of the fact there are important spatial connections that need to be considered.

Benthic structural complexity - The areas of high structural complexity generated by the Duke University benthic habitat model had an important influence on the MARXAN results because the assessment included relatively few targets offshore. Although the model received positive reviews during expert workshops, its results have not been validated (i.e., compared against direct measures of habitats and structural complexity on the sea floor). In addition, the assumption that structural complexity is correlated with measures of biological diversity has not been tested off the Southeastern coast.

Shellfish ecosystems - Shellfish ecosystems, particularly oyster reefs, were one of the major conservation targets considered in the assessment. However, the state of knowledge about the abundance, distribution, and condition of oyster reefs in the ecoregion was limited. Methods used for mapping shellfish habitat vary from state to state and in some areas information on shellfish habitat was unavailable. Oyster reefs throughout the region have been severely depleted over the last century. Knowledge about their historic distribution has been limited, and sometimes areas were identified as having significant shellfish habitat only if they were open for harvest. The South Carolina Department of Natural Resources is using high-resolution aerial photography to map intertidal oyster beds. The North Carolina Department of the Environment and Natural Resources is also working to accurately map its oyster resources in intertidal and subtidal areas. As more information becomes available on the location of intact shellfish resources, it should be incorporated into conservation area planning as well as future ecoregional assessments.

Regional threats - The suitability index developed for use in MARXAN and the qualitative threats review were based on information readily available at the ecoregional scale. A quantitative regional threats assessment will be needed to better identify areas that are the most highly threatened. TNC's conservation area planning tool, known as the 5-S framework (Low 2003), can be used to identify key systems (conservation targets and key ecological attributes that affect their viability), stresses (types of destruction, degradation, or impairment that threaten those systems), sources (agents generating stresses), strategies (activities used to abate threats), and measures of success (measures of biodiversity health and threat abatement). The 5-S framework will be used to assess threats at selected high-priority action areas in the future.

Offshore fish assemblages - The assessment used areas of high structural complexity, known or suspected hard-bottom areas, and Habitat Areas of Particular Concern as a means to incorporate offshore areas with potentially high biological diversity. Otherwise, information was not available on important spawning areas and other sites with high diversity. A NOAA-Marine Fishery Independent GIS Project (MARFIN) being carried out by the South Carolina Department of Natural Resources is gathering data to quantify the location of important fish assemblages and spawning areas from Cape Hatteras to Cape Canaveral. As this work becomes available it would be useful to incorporate it into in future refinements of this assessment and as data for conservation area planning.

PRIORITY ACTION AREAS

The planning team, the Global Marine Initiative, and TNC chapter staff qualitatively evaluated the results of the MARXAN runs and the final conservation portfolio and recommended 10 areas as initial priorities in the ecoregion; some areas consist of more than one site. (Numbers in parentheses refer to the sites illustrated in Figure 18. Information on target concentrations present in all areas is contained in Appendix 3).

- Indian River Lagoon (1 and 3)
- St. Mary's-Satilla-Cumberland Island Estuarine Complex (10 and 13)
- Altamaha-Ogeechee Estuarine Complex 16)
- ACE Basin Estuarine Complex (20)
- Sewee-Santee-Winyah Bay Estuarine Complex (23-A)
- Onslow Bight Estuarine Complex (26, 28, 29, 30, 31, 32, 33)
- Pamlico Sound-Outer Banks Estuarine Complex (34, 35, 36-A)
- Charleston Bump and Gyre Complex (23-B)
- Onslow Bight Ocean Complex (27)
- Outer Banks Ocean Complex (36-B)

A brief description of these areas follows, with a list of targets and a brief indication of possible threats. The importance and magnitude of the threats will be revised during more detailed conservation area planning. This information is intended as a starting point for future analyses of stresses, sources of stress, and potential strategies to address them.

Conservation programs are already under way in many of these action areas. In some areas, TNC has well-established programs in place. In other areas, there are existing wildlife refuges, reserves, national seashores, and other federal, state, or private conservation initiatives. Where there is overlap between those areas and the action areas identified in the assessment, we hope to be able to work with partners old and new to support their efforts and to launch new ones. In addition, we hope the assessment will act as a catalyst to encourage conservation agencies to collaborate in developing new ecosystem-based approaches to conservation across the ecoregion.

Indian River Lagoon (1 and 3)

Location and size - Northern Indian River Lagoon and adjacent nearshore waters. ~205,500 hectares

Principal targets - seagrass ecosystems, shellfish ecosystems, salt and brackish marshes, fresh marsh, intertidal scrub-shrub, sea turtle nesting beaches, reddish egrets and other colonial water birds, right whale calving grounds, nearshore hard bottom, nearshore structural complexity.

Principal threats - nutrification, pollution, altered hydrology, shoreline hardening, incompatible development, sea level rise.

The Indian River Lagoon borders and defines one-third of Florida's Atlantic coastline, stretching 156 miles from Ponce de Leon Inlet to Jupiter Inlet. The Environmental Protection Agency designated the lagoon a National Estuary Program due to its diversity and economic importance. The Indian River Lagoon has one of the most diverse bird populations anywhere on the continent and is home to nearly one-third of the nation's West Indian manatee population. Its barrier island beaches provide some of the most important sea turtle nesting habitat in the Western Hemisphere. Within this stretch of coastline, tropical and temperate climatic zones and biological ecoregions meet and overlap. This convergence has resulted in a unique and extremely diverse collection of habitats and species that occur nowhere else.

The system encompasses a series of shallow, interconnected lagoons - the Indian River, Mosquito Lagoon and Banana River - connected to the ocean by several small, widely spaced inlets. Like much of Florida, the lagoon region has had a substantial population increase, and the cumulative impacts of development-related activities have degraded water and sediment quality. Water quality in many areas is no longer sufficient to support healthy seagrass beds or to allow the unrestricted harvest of shellfish. The abundance of many important fish and wildlife species has declined.

As part of the Comprehensive Everglades Restoration Program, the U.S. Army Corps of Engineers has initiated feasibility studies to design and evaluate restoration projects for the southern and northern portions of the Indian River Lagoon. Projects developed through these studies could include construction of extensive water storage and storm water treatment areas, acquisition and restoration of natural storage and treatment areas, removal of degraded sediment, and habitat creation.

St. Mary's-Satilla-Cumberland Island Estuarine Complex (10 and 13)

Location and size - formed by the estuaries of the St. Mary's and Satilla rivers, including Cumberland Sound and Cumberland Island. ~102,000 hectares.

Principal targets - shellfish ecosystems, salt and brackish marshes, sea turtle nesting beaches, right whale calving grounds, shortnose sturgeon habitat, American oystercatcher, piping plover, nearshore structural complexity.

Principal threats - incompatible development, dredging, shipping, hardened shoreline, sea level rise, Satilla point and nonpoint source pollution, stormwater runoff, incompatible forestry and agricultural practices, new titanium mine, city and rural drainage.

The St. Mary's River forms the boundary between Georgia and Florida. It drains part of the Okefenokee Swamp and is a typical slow-flowing black-water river with very high dissolved organic carbon concentrations and variable flow rates. The Satilla River is also a black-water river. The estuaries of these rivers "bracket" Cumberland Island, Cumberland Sound, the Cumberland River, and the Cumberland Island National Seashore.

The area is typical of the Georgia coast, which is characterized by numerous inlets, estuaries, vast brackish and salt marshes, and tidal creeks. In the last 30 years, the quality and productivity of Georgia estuaries and inner shelf have declined remarkably due to both natural environmental deterioration and unwise human activities. Commercial fishery stocks have dramatically decreased with an increase in the salinity level in coastal rivers and estuaries. The rapid growth of Georgia's coastal population, human exclusion of fresh water from rivers, and pollutant material loading from the land have had a pronounced influence on the estuarine and coastal ecosystems.

Cumberland Island National Seashore comprises a significant portion of the area (nearly 15,000 hectares) as does the 18,000 hectare Timucuan Ecological and Historic Preserve, a cooperative partnership involving the National Park Service and state, local and private landowners. The Nature Conservancy is working to protect habitat on Cumberland Island and the St. Mary's River. The St. Mary's and Satilla are part of the Georgia Rivers Land Margin Ecosystem Research (LMER) Project, one of four projects funded by the National Science Foundation to examine the interactions between coastal wetlands and rivers and their adjacent oceanic ecosystems.

Several Georgia and Florida counties have formed the St. Mary's River Management Committee to ensure the long-term viability of the environmental and economic resources of the St. Mary's River.

Altamaha-Ogeechee Estuarine Complex (16)

Location and size - Formed by the estuaries of the Altamaha and Ogeechee rivers, including Ossabaw Sound, Sapelo Sound, Sapelo Island, Altamaha Sound, Ossabaw Island, Wassaw Island, and Little St. Simons Island. ~159,000 hectares.

Principal targets - shellfish ecosystems, tidal and non-tidal fresh marshes, salt and brackish marshes, intertidal scrub-shrub, forested wetlands, sea turtle nesting beaches, right whale calving grounds, shortnose sturgeon habitat, American oyster catcher, piping plover, little blue heron, black-crowned night heron, nearshore structural complexity.

Principal threats - incompatible development, hardened shoreline, sea level rise, point and nonpoint source pollution, excessive groundwater/surface water withdrawal, altered hydrology, incompatible development and forestry practices, invasive species, land conversion for agriculture and silviculture, disease (marsh die-back).

The Altamaha is the largest river of the Georgia coast and one of the largest river systems east of the Mississippi (37,600 km2). Draining the Piedmont and Coastal Plain, the Altamaha River is formed by the confluence of the Oconee and Ocmulgee rivers and flows 220 km unobstructed by dams and with no major channelization or dredging. With an extensive floodplain exceeding 20 km, it is among the least developed and biologically richest rivers on the Atlantic coast. The Altamaha accounts for 18 percent of the freshwater inputs to the South Atlantic continental shelf. Although the Ogeechee flows out of the Georgia Piedmont, most of its flow originates in watersheds on the coastal plain, resulting in a black-water system.

The Altamaha-Ogeechee estuary is typical of the Georgia coast and is characterized by vast salt and brackish marshes, numerous inlets, and tidal creeks. Some of the Southeast's largest wintering areas for piping plover are found on the barrier islands.

The Nature Conservancy began to actively protect habitat in the Altamaha watershed in the late 1960s and formed the Altamaha River Bioreserve project in 1991. TNC helped to protect Wassaw and Ossabaw islands in 1969 and the 1970s.

The Altamaha-Ogeechee Estuarine Complex includes the Sapelo Island National Estuarine Research Reserve and four national wildlife refuges (Wolf Island, Blackbeard Island, Harris Neck, and Wassaw). The area is also encompassed by the new Georgia Coastal Ecosystems Long Term Ecological Research Project, and the Altamaha and Ogeechee were included in the Georgia Rivers LMER project.

The rapid growth of Georgia's coastal population is having a pronounced influence on this system.

ACE Basin Estuarine Complex (20)

Location and size - The estuarine component of the ACE Basin, including St. Helena Sound as well as Port Royal and the mouth of the Broad River. ~147,000 hectares.

Principal targets - shellfish ecosystems, tidal and non-tidal fresh marshes, salt and brackish marshes, intertidal scrub-shrub, sea turtle nesting beaches, American oyster catcher, piping plover, little blue heron, green heron, yellow-crowned night heron, nearshore structural complexity.

Principal threats - habitat loss from incompatible development, agriculture and silviculture, point and non-point source pollution and nutrification, hardened shorelines, resource depletion.

The ACE Basin - formed by the confluence of three undammed, free-flowing rivers (the Ashepoo, Combahee and Edisto) - is one of the largest undeveloped estuaries on the Atlantic coast. It encompasses a diverse mixture of ecosystems and the highly productive waters of St. Helena Sound. For purposes of this assessment, we extend the traditional boundaries of the ACE Basin south across Hunting, Fripp, Pritchards and Bay Point islands, through Port Royal Sound and into the lower reaches of the Broad River.

Otter Island, near the mouths of the Ashepoo and South Edisto rivers, is one of South Carolina's most important sites for nesting loggerhead turtles. Other significant nesting beaches also occur on Hunting, Fripp, Pritchards and Bay Point islands. Large populations of American oystercatchers, piping plovers and colonial water birds use the marshes, sand flats and dunes for both breeding and wintering. Nearly 45 percent of South Carolina's intertidal oyster reefs are located in Beaufort County, which constitutes much of this area.

Long one of TNC's major conservation areas, the ACE Basin is also the site of a National Estuarine Research Reserve program. ACE Basin National Wildlife Refuge, Pinckney Island National Wildlife Refuge, Hunting Island State Park, and several state heritage parks and wildlife management areas are found here, along with extensive areas of privately protected lands. Private landowners, federal agencies, state agencies, and private conservation groups have formed the ACE Basin Task Force to advance land conservation and compatible resource management in the project area and to minimize incompatible land uses This is particularly important since three fast-growing cities (Charleston, Beaufort, Savannah) are within an hour's drive and pose the potential for rapid urbanization.

Sewee-Santee-Winyah Bay Estuarine Complex (23-A)

Location and size - Bulls Bay, Santee River estuary, Winyah Bay, North Inlet, and adjacent nearshore portions of the Charleston Gyre. ~199,500 hectares.

Principal targets - shellfish ecosystems, salt and brackish marshes, fresh marshes, intertidal scrub-shrub, forested wetlands, sea turtle nesting beaches, shortnose sturgeon, American oyster catcher, piping plover, little blue heron, black skimmer, nearshore hard bottom, nearshore structural complexity.

Principal threats - incompatible commercial and residential development, altered hydrology, nutrification, sedimentation, shipping, dredging, hardened shorelines, sea level rise.

The Sewee-Santee-Winyah Bay conservation area encompasses the estuaries of Bulls Bay, the Santee River, Winyah Bay, and North Inlet and extends offshore to include several areas of potentially important hard bottom. The region contains South Carolina's largest complex of tidal fresh-water wetlands and more than 40 miles of undeveloped coastline, barrier islands, and inlets. Exceptionally large shorebird and colonial waterbird populations use the area during nearly every stage of their life cycles. The most densely-nested, sea turtle beaches in the ecoregion are located on Cape and Lighthouse islands.

Much of the area is in conservation, including Cape Romain National Wildlife Refuge, Francis Marion National Forest, North Inlet-Winyah Bay National Estuarine Research Reserve, numerous state wildlife management areas and heritage preserves and privately protected lands.
A major threat to the Sewee-Santee-Winyah Bay system is the altered hydrology of the rivers that feed the estuaries. On the Santee River, diversions to the Cooper River for power generation and navigation in Charleston Harbor reduce the flow for extended periods. On the Pee Dee River, one of five rivers that flow into Winyah Bay, the operation of hydropower facilities in North Carolina leads to extreme low flows and extremely high summer peaking flows. Impacts include dewatering of riverine and coastal habitat, saltwater intrusion into fresh-water ecosystems, intense flows during periods when slack-water spawners and larval fish need quiet water, and the continuous resuspension of sediment creating perpetually turbid conditions.

A second critical threat is rapid growth of urban and suburban development emanating from Charleston to the south, and Myrtle Beach to the north.

Onslow Bight Estuarine Complex (26, 28, 29, 30, 31, 32, 33)

Location and size - From the lower Northeast Cape Fear River to the Pamlico River, encompassing Cape Lookout National Seashore, Bogue Sound, Core Sound, and southwestern Pamlico Sound. ~155,000 hectares.

Principal targets - seagrass ecosystems, shellfish ecosystems, salt and brackish marshes, intertidal scrub-shrub, shortnose sturgeon, piping plover, common tern, black skimmer.

Principal threats - habitat loss from incompatible development agriculture and silviculture, hydrologic alteration, point and non-point source pollution, sedimentation, nutrification, habitat alteration due to harmful fishing practices, disease (e.g.,Pfiesteria, red tide), shoreline alteration, shipping, dredging, sea level rise.

The Onslow Bight extends from the lower Northeast Cape Fear River to the Pamlico River and encompasses the Cape Lookout National Seashore, Bogue Sound, Core Sound, and the southwestern portion of Pamlico Sound. The area is unified by several ecological features and functions, including the fire-dependent longleaf pine/pocosin ecosystem on the terrestrial landscape and expansive salt marsh systems sheltered from the ocean by a strand of narrow barrier islands and sounds.

Seven separate sites identified in the assessment lie entirely or in part within the boundaries of the larger Onslow Bight landscape. The Onslow Bight Working Group, a consortium of state and federal agencies and private conservation organizations, including TNC, is working to develop a comprehensive conservation plan for the entire area. To date the group has focused almost exclusively on terrestrial and fresh-water issues but expects to consider marine and estuarine issues in the near future.

The Onslow Bight encompasses many large conservation areas, including Cape Lookout National Seashore, Croatan National Forest and Cedar Island National Wildlife Refuge. Other large managed areas include Marine Corps Base Camp Lejeune, Marine Corps Air Station Cherry Point, North River Farms, and several state parks and game lands.

Pamlico Sound-Outer Banks Estuarine Complex (34, 35, 36-A)

Location and size - Pamlico Sound from Ocracoke Inlet north to Oregon Inlet, including the southern shore of the Albemarle-Pamlico Peninsula, Hatteras and Ocracoke Islands, and adjacent nearshore waters. ~160,500 hectares.

Principal targets - seagrass ecosystems, shellfish ecosystems, brackish marshes, fresh marshes, intertidal scrub-shrub, sea turtle nesting beaches, piping plover, common tern, black skimmer, nearshore hard bottom, nearshore structural complexity.

Principal threats - habitat loss from incompatible development and agriculture; increased impervious surfaces and higher levels of storm-water runoff; habitat alteration due to harmful fishing practices; nutrification; disease (e.g. Pfiesteria, red tide); hydrologic alteration; sedimentation; pollution; shoreline alteration; dredging, sea level rise.

The Albemarle-Pamlico system - with a watershed of more than 77,000 km2 - is the second largest estuarine system in the United States, second only to the Chesapeake Bay. It is composed of seven sounds, has inflows from five major river basins, and is separated from the Atlantic Ocean by the lengthy barrier island strand known as the Outer Banks. Pamlico Sound, the largest of the sounds, is more than 500,000 hectares and is connected to the ocean by Oregon, Hatteras and Ocracoke inlets.

This large estuary functions as a settling basin where coastal rivers meet the sea. As such, the flow of water between the rivers and the estuaries, and between the estuaries and the ocean, must be maintained so that settlement of transported larvae to the estuary is successful. The sound is of prime importance for fishery productivity in the ecoregion; nearly all fish and shellfish species in coastal North Carolina occupy the estuary at some point in their life cycles, including many offshore spawners. Oregon Inlet provides the only opening into Pamlico Sound north of Cape Hatteras for larvae spawned and transported from the Mid-Atlantic Bight. Larval fish diversity in North Carolina's inlets is very high (e.g., 61 larval species have been found in Oregon Inlet) (NC-CHPP 2004).

Extensive ditching and draining of the Albemarle-Pamlico peninsula and hydrological alteration of the rivers feeding the system have caused major changes in the salinity of the estuary. Overfishing and destructive fishing practices have decimated the oyster populations of Pamlico Sound. Pollution and increased turbidity have reduced the distribution of seagrass beds throughout the estuary. Rapid development and soaring tourism on the Outer Banks have introduced new threats, such as habitat destruction from off-road vehicle use, increased shoreline hardening, and beach nourishment projects.

The Pamlico Sound-Outer Banks area includes the Cape Hatteras National Seashore, three national wildlife refuges, portions of the North Carolina National Estuarine Research Reserve, and the Albemarle-Pamlico National Estuary Program.

Charleston Bump and Gyre Complex (23-B)

Location and size - Offshore extending from near Winyah Bay to the continental shelf edge, mainly between 32° and 34° N. latitude. ~1,021,500 hectares.

Principal targets - hard bottom, areas of high structural complexity and Habitat Area of Particular Concern (Charleston Bump and Gyre).

Principal threats - overexploitation, introduction of alien species, land-based activities, and habitat alteration and destruction.

The topographic irregularity southeast of Charleston known as the Charleston Bump is an area of productive seafloor that rises abruptly from 700 to 300 meters within the short distance of about 20 km. The Charleston Bump is located approximately 32° 44' N. latitude and 78° 06' W. longitude and at an angle which is approximately transverse to both the general isobath pattern and the Gulf Stream currents. Although two or three large meanders and eddies can form downstream of the Charleston Bump, the cyclonic Charleston Gyre is the largest and the most prominent feature. This consistent upwelling of nutrient-rich deep waters from the depths over 450 meters to the near-surface layer is the main steady source of nutrients near the shelf break within the entire ecoregion, and it contributes significantly to primary and secondary production in the region. The Charleston Gyre is considered an essential nursery habitat for some offshore fish species with pelagic stages, such as reef fishes. It also appears to have an important role in the retention of fish eggs and larvae and their transport onshore (SAFMC 1998).

Onslow Bight Ocean Complex (including Big Rock and Ten Fathom Ledge) (27)

Location and size - in the Onslow Bay area of North Carolina, directly south of Cape Lookout. ~327,000 hectares.

Principal targets - hard bottom, areas of high structural complexity, and the Big Rock and Ten Fathom Ledge Habitat Areas of Particular Concern.

Principal threats - overexploitation, introduction of alien species, land-based activities, and habitat alteration and destruction.

Ten Fathom Ledge is located in 95-120m depth on the continental shelf near the southern edge of Cape Lookout Shoals. The area encompasses numerous patch reefs of coral-algal-sponge growth on rock outcroppings distributed over 350km2 of ocean floor. The Big Rock area encompasses 93km2 of deep drowned reef around the 50-100m isobath on the outer shelf and upper slope approximately 36 miles south of Cape Lookout. Unique bottom topography at both sites produces oases of productive bottom relief with diverse and productive epifaunal and algal communities. Approximately 150 species of reef-associated species have been documented from the two sites (SAFMC 1998).

Outer Banks Ocean Complex (including The Point or Hatteras Corner) (36-B)

Location and size - Extending from near Oregon Inlet offshore to the continental shelf edge and south to Cape Hatteras. ~246,000 hectares.

Principal targets - hard bottom, areas of high structural complexity, and Habitat Area of Particular Concern (The Point/Hatteras Corner).

Principal threats - overexploitation, introduction of alien species, land-based activities, and habitat alteration and destruction.

The confluence of the Gulf Stream with as many as three other water masses off Cape Hatteras creates a dynamic and highly productive environment known as The Point or Hatteras Corner. Adults of many highly migratory species congregate in the area. There is also a great diversity of larval fishes, marine mammals, and seabirds (SAFMC 1998).

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TABLES

Table 1: Conservation Targets, Quantities, Characteristic Species		
CONSERVATION TARGETS	**ESTIMATED QUANTITY OF TARGET**	**SCIENTIFIC NAMES AND CHARACTERISTIC SPECIES**
Seagrass Ecosystems	66,737 ha	*Zostera marina, Halodule wrightii, Rupia maritima, Halophila johnsonii, Halophila decipiens*
Shellfish Ecosystems	379,990 ha	*Crassostrea virginica*, *Archosargus probatocephalus, Pogonias cromis, Sciaenops ocellatus*, blennies, gobies, toadfish, portunid crabs, penaeid and caridean shrimp, macroinvertebrates, macroalgae
Mixed Sand and Gravel Beach	53 km	Sea turtles, shorebirds, mole crabs, amphipods, isopods
Gravel and Shell Beach	47 km	Sea turtles, shorebirds, mole crabs, amphipods, isopods
Fine Sand Beach	833 km	Sea turtles, shorebirds, mole crabs, amphipods, isopods
Coarse Sand Beach	993 km	Sea turtles, shorebirds, mole crabs, amphipods, isopods
Sheltered Tidal Flat with Oysters	5 km	Algae, polychaetes, bivalves
Sheltered Tidal Flat	18 km	Algae, polychaetes, bivalves
Exposed Tidal Flat	33 km	Algae, polychaetes, bivalves
Exposed Scarp with Clay	5 km	
Tidal Fresh Marsh	6,093 ha	*Juncus spp., Scirpus spp., Typha spp., Cladium spp.*
Fresh Marsh	23,253 ha	*Cyperus spp., Elatine spp., Eleocharis spp., Salix spp., Scirpus spp. Typha spp.*
Intertidal Scrub-Shrub	22,213 ha	*Myrica cerifera, Cyperus spp*. Woody vegetation less than 6 m tall, including trees and shrubs stunted by environmental conditions.
Forested Wetlands	1,277 ha	*Acer spp., Alnus spp., Ilex. spp., Myrica, spp., Nyssa spp., Pinus spp., Quercus spp. Salix spp.*
Irregularly Flooded Salt Marsh	165,193 ha	*Juncus roemerianus, Spartina patens, Spartina alterniflora, Cladium jamaicense, Carex spp.*
Regularly Flooded Salt Marsh	251,517 ha	*Spartina alterniflora, Juncus roemerianus*
Salt Marsh with Variable Flooding	3,980 ha	*Juncus roemerianus, Spartina patens, Spartina alterniflora, Cladium jamaicense, Carex spp.*
Sea Turtle Nesting Beaches	1,790 km	*Carretta carretta*, *Dermochelys coriacea, Chelonia mydas*
Right Whale Calving Grounds	494,093 ha	*Eubalaena glacialis*
Shortnose Sturgeon	113,263 ha	*Acipenser brevirostrum*
American Oystercatcher	4,817 ind	*Haematopus paliatus*
Piping Plover	30,342 ha	*Charadrius melodus*
Yellow-crowned Night Heron	50 col	*Nyctanassa violacea*
Wood Stork	13 col	*Mycteria americana*
Little Blue Heron	90 col	*Egretta caerulea*
Green Heron	57 col	*Butorides virescens*
Common Tern	100 col	*Sterna hirundo*
Black Skimmer	90 col	*Rhynchops niger*
Black-crowned Night Heron	90 col	*Nycticorax nycticorax*
Reddish Egret	1 col	*Egretta rufescens*
Hard Bottom at depths < than 50m	1,076,553 ha	Groupers, snappers, grunts, trigger fish, tilefish, blennies, gobies, sharks, eels.
Hard Bottom at depths > than 50m	113,027 ha	Groupers, snappers, grunts, trigger fish, tilefish, blennies, gobies, sharks, eels.
Structural Complexity at depths < 50m	170,787 ha	Groupers, snappers, grunts, sea bass, trigger fish, tilefish, blennies, gobies, sharks, eels,
Structural Complexity at depths > 50m	13,503 ha	Groupers, snappers, grunts, sea bass, trigger fish, tilefish, blennies, gobies, sharks, eels,
Habitat Area of Particular Concern (Charleston Bump Complex)	4,292,133 ha	Wreckfish, groupers, snappers, grunts, sea bass, trigger fish, tilefish, blennies, gobies, sharks, eels,
Habitat Area of Particular Concern (The Point, Ten Fathom Ledge and Big Rock)	172,940 ha	Highly migratory oceanic species, many larval and juvenile fishes (tuna, mackerel, flounder, drum, snapper, sea bass, porgy, etc.), groupers, snappers, grunts, blennies.

Table 2

TABLE 2: CONSERVATION GOALS		
CONSERVATION TARGETS	ESTIMATED QUANTITY OF TARGET	CONSERVATION GOAL
Seagrass Ecosystems	66,737 ha	30%
Shellfish Ecosystems	379,990 ha	30%
Mixed Sand and Gravel Beach	53 km	30%
Gravel and Shell Beach	47 km	30%
Fine Sand Beach	833 km	30%
Coarse Sand Beach	993 km	30%
Sheltered Tidal Flat with Oysters	5 km	40%
Sheltered Tidal Flat	18 km	40%
Exposed Tidal Flat	33 km	40%
Exposed Scarp with Clay	5 km	40%
Tidal Fresh Marsh	6,093 ha	30%
Fresh Marsh	23,253 ha	30%
Intertidal Scrub-Shrub	22,213 ha	30%
Forested Wetlands	1,277 ha	30%
Irregularly Flooded Salt Marsh	165,193 ha	30%
Regularly Flooded Salt Marsh	251,517 ha	30%
Salt Marsh with Variable Flooding	3,980 ha	30%
Sea Turtle Nesting Beaches	1,790 km	30%
Right Whale Calving Grounds	494,093 ha	30%
Short-nose Sturgeon	113,263 ha	30%
American Oystercatcher	4,817 ind	30%
Piping Plover	30,342 ha	50%
Yellow-crowned Night Heron	50 col	30%
Wood Stork	13 col	30%
Little Blue Heron	90 col	30%
Green Heron	57 col	30%
Common Tern	100 col	30%
Black Skimmer	90 col	30%
Black-crowned Night Heron	90 col	30%
Reddish Egret	1 col	100%
Hard Bottom at depths < than 50m	1,076,553 ha	30%
Hard Bottom at depths > than 50m	113,027 ha	30%
Structural Complexity at depths < 50m	170,787 ha	30%
Structural Complexity at depths > 50m	13,503 ha	30%
Habitat Area of Particular Concern (Charleston Bump Complex)	4,292,133 ha	30%
Habitat Area of Particular Concern (The Point, Ten Fathom Ledge and Big Rock)	172,940 ha	100%

TABLE 3: SUITABILITY INDEX			
SUITABILITY FACTOR	UNIT OF MEASURMENT	SUITABILITY POINTS	DATA SOURCE
Basic cost per planning unit	11,903 units (1,500 hectare hexagons)	35	
Mean population change	0 – 10% increase 10 – 25% increase 25 – 50% increase > 50% increase	0 5 10 20	Census Bureau
Housing density	0 – 100 housing units 100 – 25 units 250 – 1000 units > 1,000 units	0 5 10 20	Census Bureau
Road density	0 km 0 – 25 km 26 – 50 km > 50 km	0 5 10 20	Census Bureau
Major ports	Individual port facilities	5 each	USACE-Navigation Data Center
Major shipping lanes	0 tons shipped 1 - 2 million tons 2 – 5 million tons 5 – 10 million tons > 10 million tons	0 5 10 15 20	USACE-Navigation Data Center
Dredged shipping channels	Individual dredging projects	5 each	USACE-Navigation Data Center
Hardened shorelines	0 km 1 - 10 km 10 - 20 km > 20 km	0 10 20 30	NOAA-Environmental Sensitivity Index and National Wetlands Inventory
Superfund sites	Individual sites	20 each	NOAA-Ocean Planning Information System
NPDES permits	Individual permits	5 each	NOAA-Ocean Planning Information System
Offshore dredge disposal sites	Individual sites	20 each	NOAA-Ocean Planning Information System

Table 4

TABLE 4: MARXAN "BEST SOLUTION" RESULTS						
CONSERVATION TARGET	ESTIMATED QUANTITY OF TARGET	GOAL	QUANTITY TO MEET GOAL	QUANTITY IN "BEST SOLUTION"	% OF QUANTITY IN SOLUTION/GOAL	GOAL MET
Seagrass Ecosystems	66,737 ha	30%	20,021	25,406	127%	Yes
Shellfish Ecosystems	379,990 ha	30%	113,997	131,916	116%	Yes
Mixed Sand and Gravel Beach	53 km	30%	16	35	221%	Yes
Gravel and Shell Beach	47 km	30%	14	16	113%	Yes
Fine Sand Beach	833 km	30%	250	286	115%	Yes
Coarse Sand Beach	993 km	30%	298	390	131%	Yes
Sheltered Tidal Flat with Oysters	5 km	40%	2	3	128%	Yes
Sheltered Tidal Flat	18 km	40%	7	12	172%	Yes
Exposed Tidal Flat	33 km	40%	13	20	154%	Yes
Exposed Scarp with Clay	5 km	40%	2	2	103%	Yes
Tidal Fresh Marsh	6,093 ha	30%	1,828	2,859	156%	Yes
Fresh Marsh	23,253 ha	30%	6,976	8,790	126%	Yes
Intertidal Scrub-Shrub	22,213 ha	30%	6,664	8,144	122%	Yes
Forested Wetlands	1,277 ha	30%	383	518	135%	Yes
Irregularly Flooded Salt Marsh	165,193 ha	30%	49,558	49,884	101%	Yes
Regularly Flooded Salt Marsh	251,517 ha	30%	75,455	80,810	107%	Yes
Salt Marsh with Variable Flooding	3,980 ha	30%	1,194	2,007	168%	Yes
Sea Turtle Nesting Beaches	1,790 ha	30%	537	732	136%	Yes
Right Whale Calving Grounds	494,093 ha	30%	148,228	150,100	101%	Yes
Shortnose Sturgeon Habitat	113,263 ha	30%	33,979	34,352	101%	Yes
American Oystercatcher	4,817 ind	30%	1,445	2,037	141%	Yes
Piping Plover	30,342 ha	50%	15,171	18,351	121%	Yes
Yellow-crowned Night Heron	50 col	30%	15	19	127%	Yes
Wood Stork	13 col	30%	4	7	175%	Yes
Little Blue Heron	90 col	30%	27	37	137%	Yes
Green Heron	57 col	30%	17	21	124%	Yes
Common Tern	100 col	30%	30	50	167%	Yes
Black Skimmer	90 col	30%	27	47	174%	Yes
Black-crowned Night Heron	90 col	30%	27	39	144%	Yes
Redddish Egret	1 col	100%	1	1	100%	Yes
Hard Bottom < 50m	1,076,553 ha	30%	322,966	325,345	101%	Yes
Hard Bottom > 50m	113,027 ha	30%	33,908	34,098	101%	Yes
Benthic Complexity < 50m	170,787 ha	30%	51,236	51,242	100%	Yes
Benthic Complexity < 50m	13,503 ha	30%	4,051	4,275	106%	Yes
HAPC – Charleston Bump and Gyre Complex	4,292,133 ha	30%	1,287,640	1,288,009	100%	Yes
HAPC – The Point, 10-Fathom Ledge and Big Rock	172,940 ha	100%	172,940	172,940	100%	Yes

TABLE 5: FINAL CONSERVATION PORTFOLIO RESULTS						
CONSERVATION TARGET	ESTIMATED QUANTITY OF TARGET	GOAL	QUANTITY TO MEET GOAL	QUANTITY IN FINAL PORTFOLIO	% OF QUANTITY IN PORTFOLIO/GOAL	GOAL MET
Seagrass Ecosystems	66,737 ha	30%	20,021	36,266	181%	Yes
Shellfish Ecosystems	379,990 ha	30%	113,997	206,769	181%	Yes
Mixed Sand and Gravel Beach	53 km	30%	16	2	13%	No
Gravel and Shell Beach	47 km	30%	14	0	0%	No
Fine Sand Beach	833 km	30%	250	421	168%	Yes
Coarse Sand Beach	993 km	30%	298	394	132%	Yes
Sheltered Tidal Flat with Oysters	5 km	40%	2	3	150%	Yes
Sheltered Tidal Flat	18 km	40%	7	12	171%	Yes
Exposed Tidal Flat	33 km	40%	13	20	154%	Yes
Exposed Scarp with Clay	5 km	40%	2	1	50%	No
Tidal Fresh Marsh	6,093 ha	30%	1,828	5,532	303%	Yes
Fresh Marsh	23,253 ha	30%	6,976	21,136	303%	Yes
Intertidal Scrub-Shrub	22,213 ha	30%	6,664	9,396	141%	Yes
Forested Wetlands	1,277 ha	30%	383	695	181%	Yes
Irregularly Flooded Salt Marsh	165,193 ha	30%	49,558	67,269	136%	Yes
Regularly Flooded Salt Marsh	251,517 ha	30%	75,455	129,824	172%	Yes
Salt Marsh with Variable Flooding	3,980 ha	30%	1,194	3,232	271%	Yes
Sea Turtle Nesting Beaches	1,790 ha	30%	537	871	162%	Yes
Right Whale Calving Grounds	494,093 ha	30%	148,228	94,013	63%	No
Shortnose Sturgeon Habitat	113,263 ha	30%	33,979	44,985	132%	Yes
American Oystercatcher	4,817 ind	30%	1,445	3,290	228%	Yes
Piping Plover	30,342 ha	50%	15,171	21,153	139%	Yes
Yellow Crown Night Heron	50 col	30%	15	22	147%	Yes
Wood Stork	13 col	30%	4	10	250%	Yes
Little Blue Heron	90 col	30%	27	49	181%	Yes
Green Heron	57 col	30%	17	27	159%	Yes
Common Tern	100 col	30%	30	51	170%	Yes
Black Skimmer	90 col	30%	27	52	193%	Yes
Black Crown Night Heron	90 col	30%	27	57	211%	Yes
Red Egret	1 col	100%	1	1	100%	Yes
Hard Bottom < 50m	1,076,553 ha	30%	322,966	296,397	92%	No
Hard Bottom > 50m	113,027 ha	30%	33,908	26,562	78%	No
Benthic Complexity < 50m	170,787 ha	30%	51,236	54,670	107%	Yes
Benthic Complexity > 50m	13,503 ha	30%	4,051	2,834	70%	No
HAPC – Charleston Bump and Gyre Complex	4,292,133 ha	30%	1,287,640	1,265,550	98%	Yes
HAPC – The Point, 10-Fathom Ledge and Big Rock	172,940 ha	100%	172,940	172,940	100%	Yes

MAPS

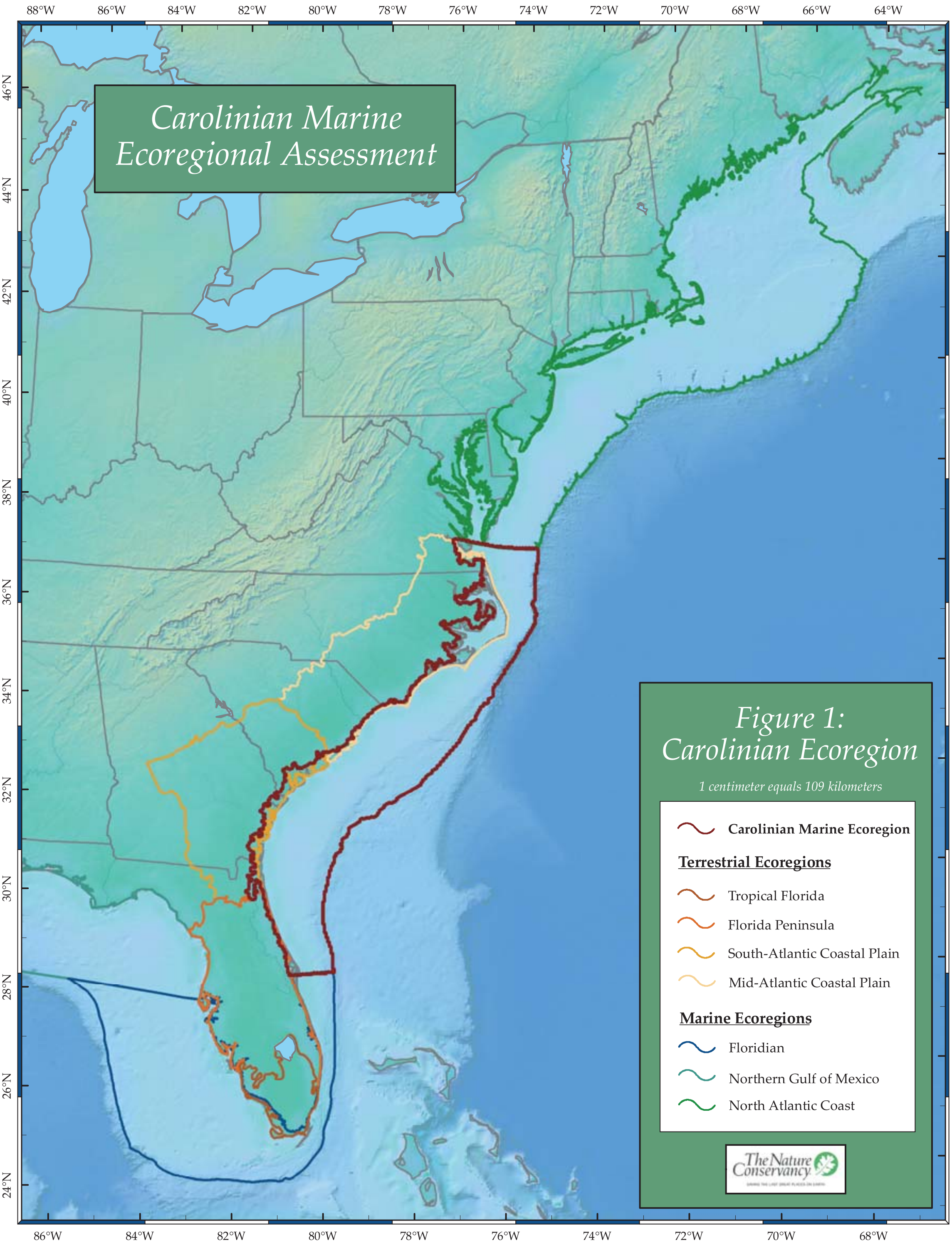
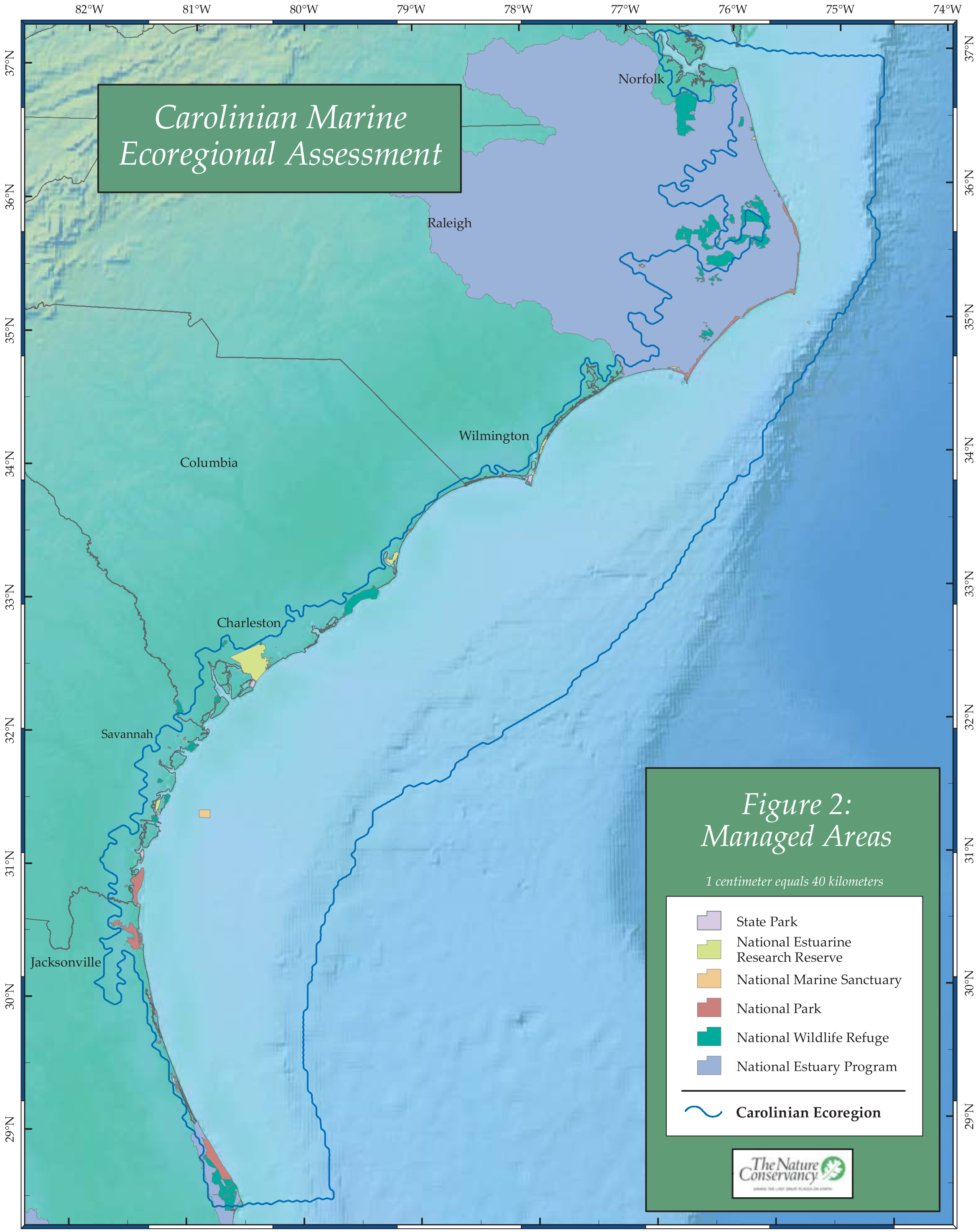

Carolinian Marine Ecoregional Assessment
Figure 1: Carolinian Ecoregion
1 centimeter equals 109 kilometers
Carolinian Marine Ecoregion
Terrestrial Ecoregions
Tropical Florida
Florida Peninsula
South-Atlantic Coastal Plain
Mid-Atlantic Coastal Plain
Marine Ecoregions
Floridian
Northern Gulf of Mexico
North Atlantic Coast
The Nature Conservancy
88°W
86°W
84°W
82°W
80°W
78°W
76°W
74°W
72°W
70°W
68°W
66°W
64°W
46°N
44°N
42°N
40°N
38°N
36°N
34°N
32°N
30°N
28°N
26°N
24°N

Figure 2



Carolinian Marine Ecoregional Assessment
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Figure 2: Managed Areas
1 centimeter equals 40 kilometers
State Park
National Estuarine Research Reserve
National Marine Sanctuary
National Park
National Wildlife Refuge
National Estuary Program
Carolinian Ecoregion
The Nature Conservancy

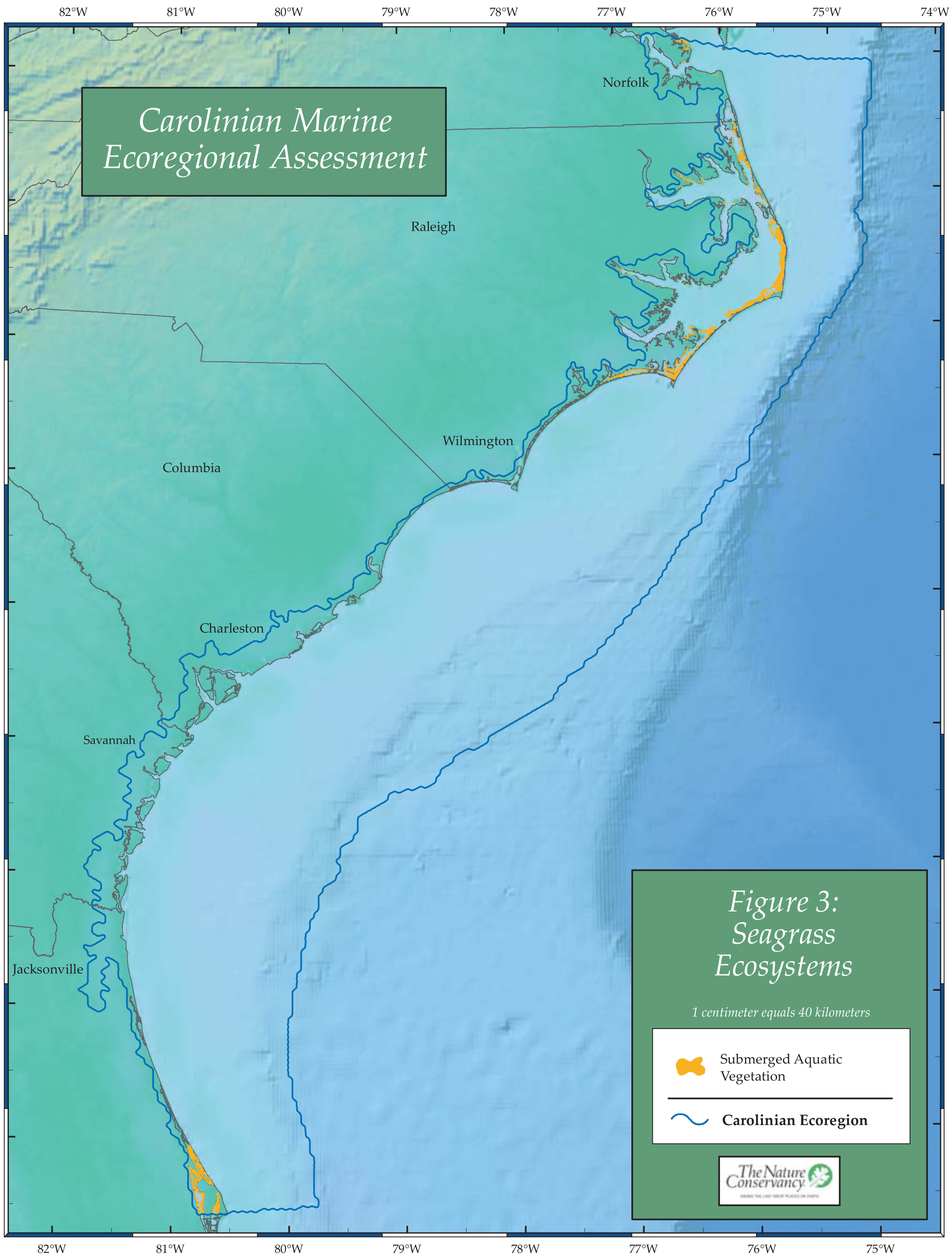
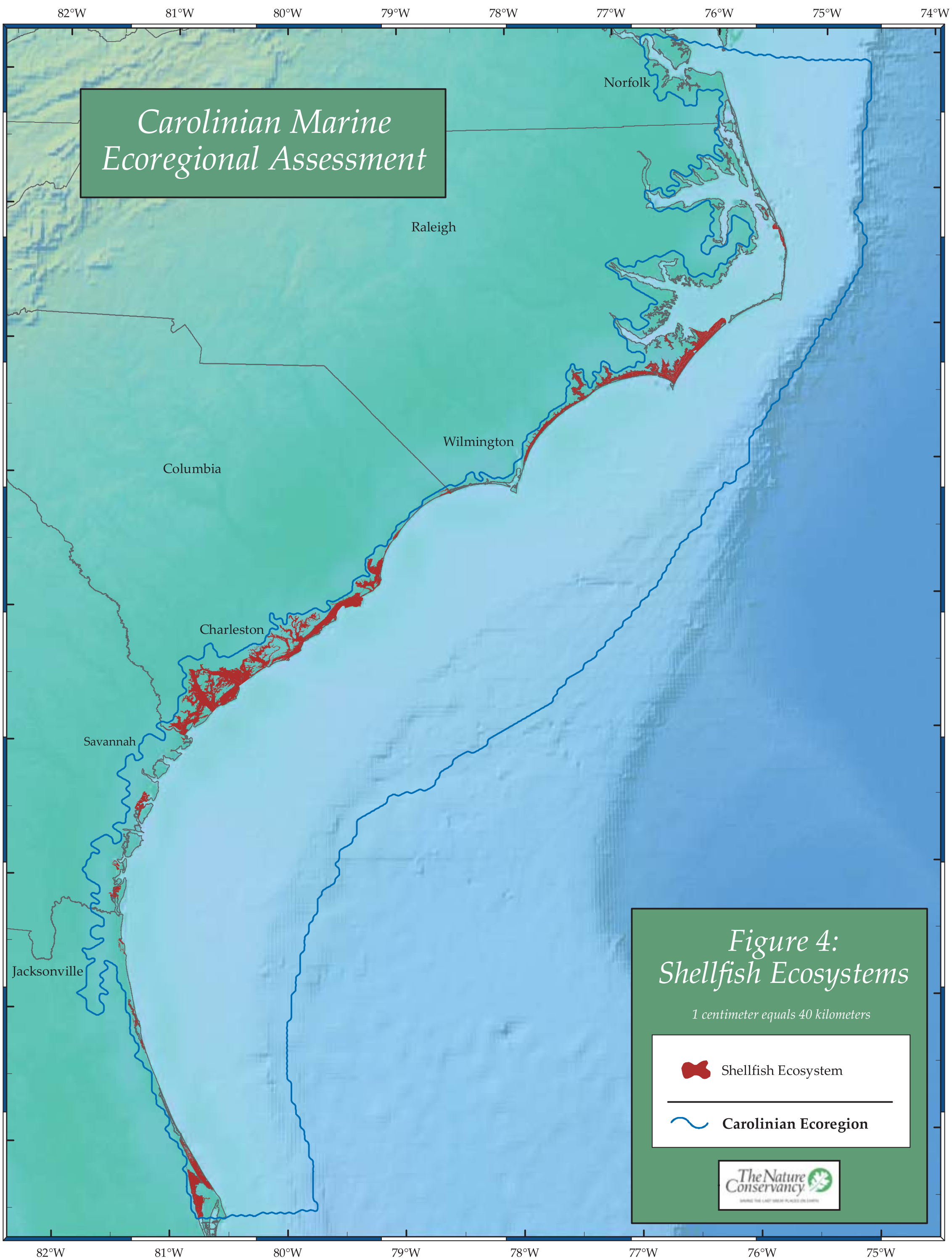

Carolinian Marine Ecoregional Assessment
Figure 3: Seagrass Ecosystems
1 centimeter equals 40 kilometers
Submerged Aquatic Vegetation
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

Figure 4


Carolinian Marine Ecoregional Assessment
Figure 4: Shellfish Ecosystems
1 centimeter equals 40 kilometers
Shellfish Ecosystem
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

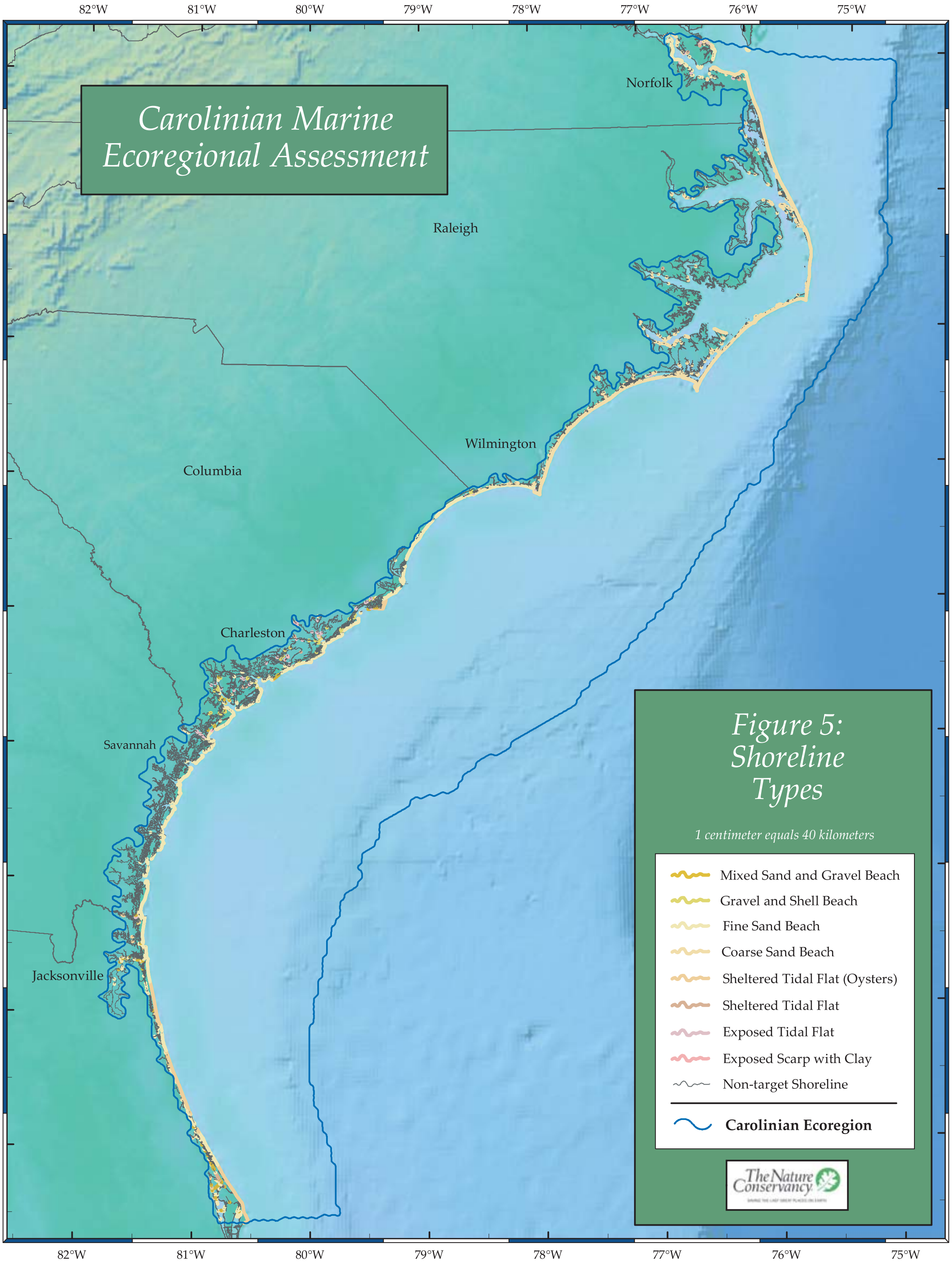
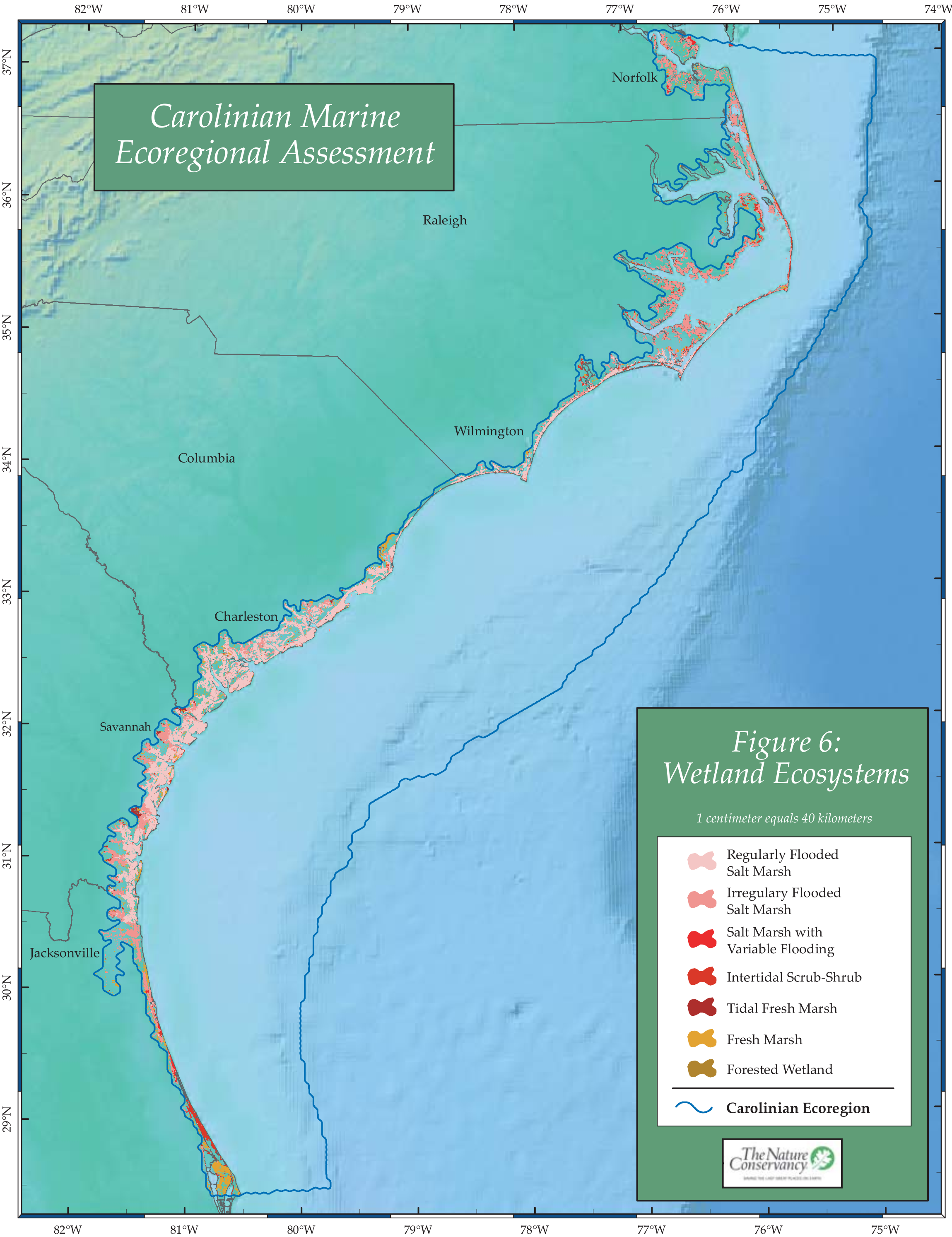
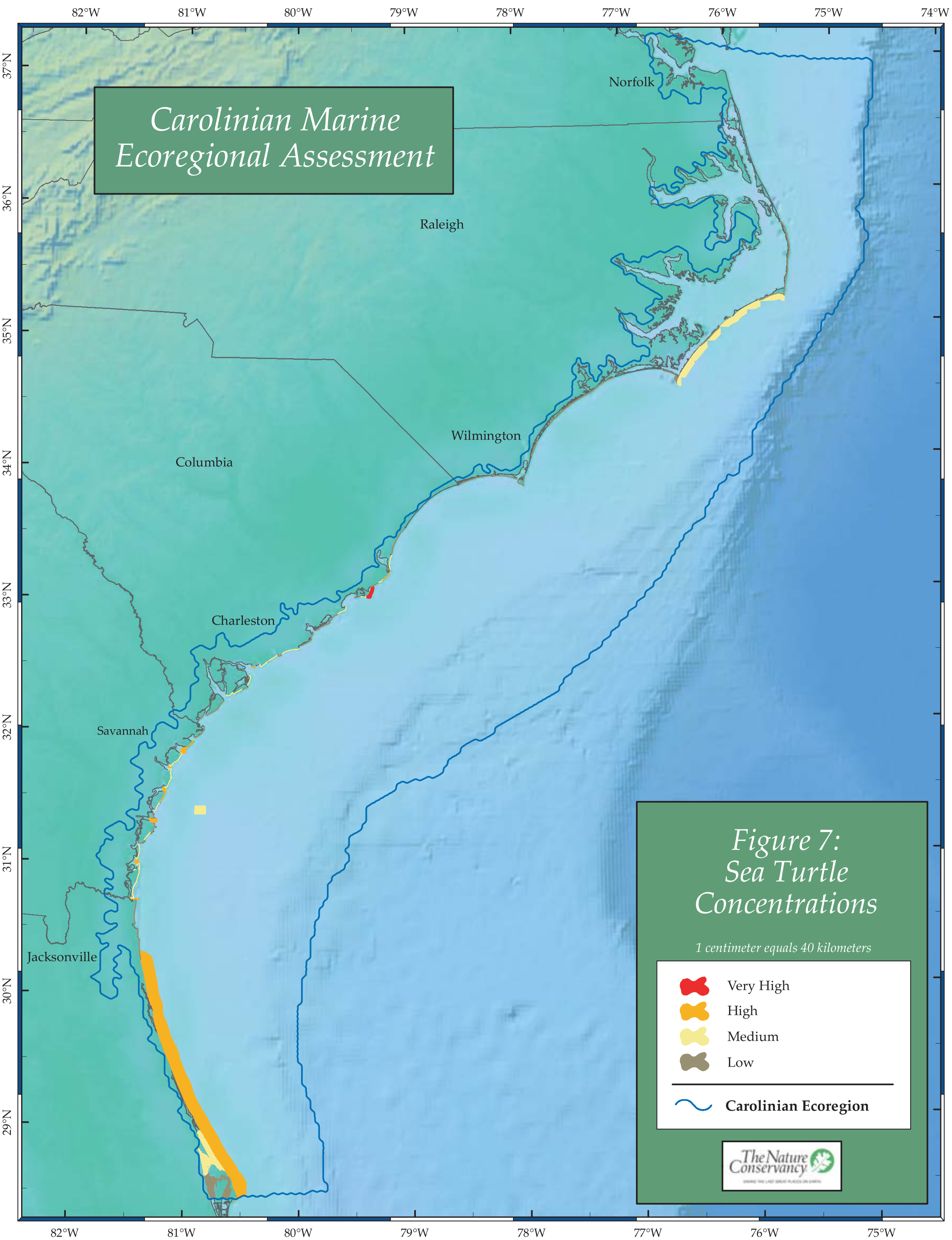

Carolinian Marine
Ecoregional Assessment
Figure 5:
Shoreline
Types
1 centimeter equals 40 kilometers
Mixed Sand and Gravel Beach
Gravel and Shell Beach
Fine Sand Beach
Coarse Sand Beach
Sheltered Tidal Flat (Oysters)
Sheltered Tidal Flat
Exposed Tidal Flat
Exposed Scarp with Clay
Non-target Shoreline
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

Figure 6

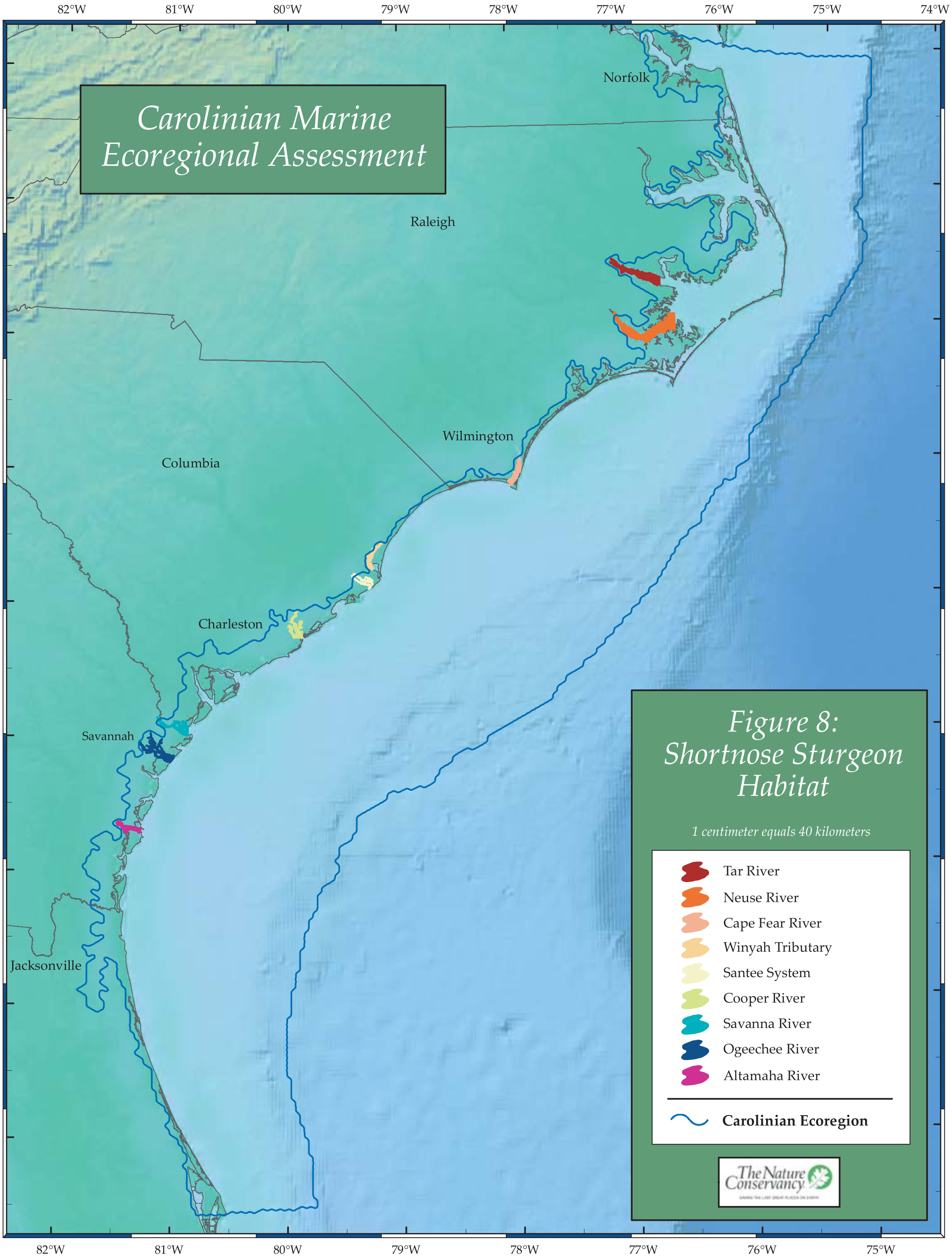


Carolinian Marine Ecoregional Assessment
Figure 6: Wetland Ecosystems
1 centimeter equals 40 kilometers
Regularly Flooded Salt Marsh
Irregulary Flooded Salt Marsh
Salt Marsh with Variable Flooding
Intertidal Scrub-Shrub
Tidal Fresh Marsh
Fresh Marsh
Forested Wetland
Carolinian Ecoregion
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

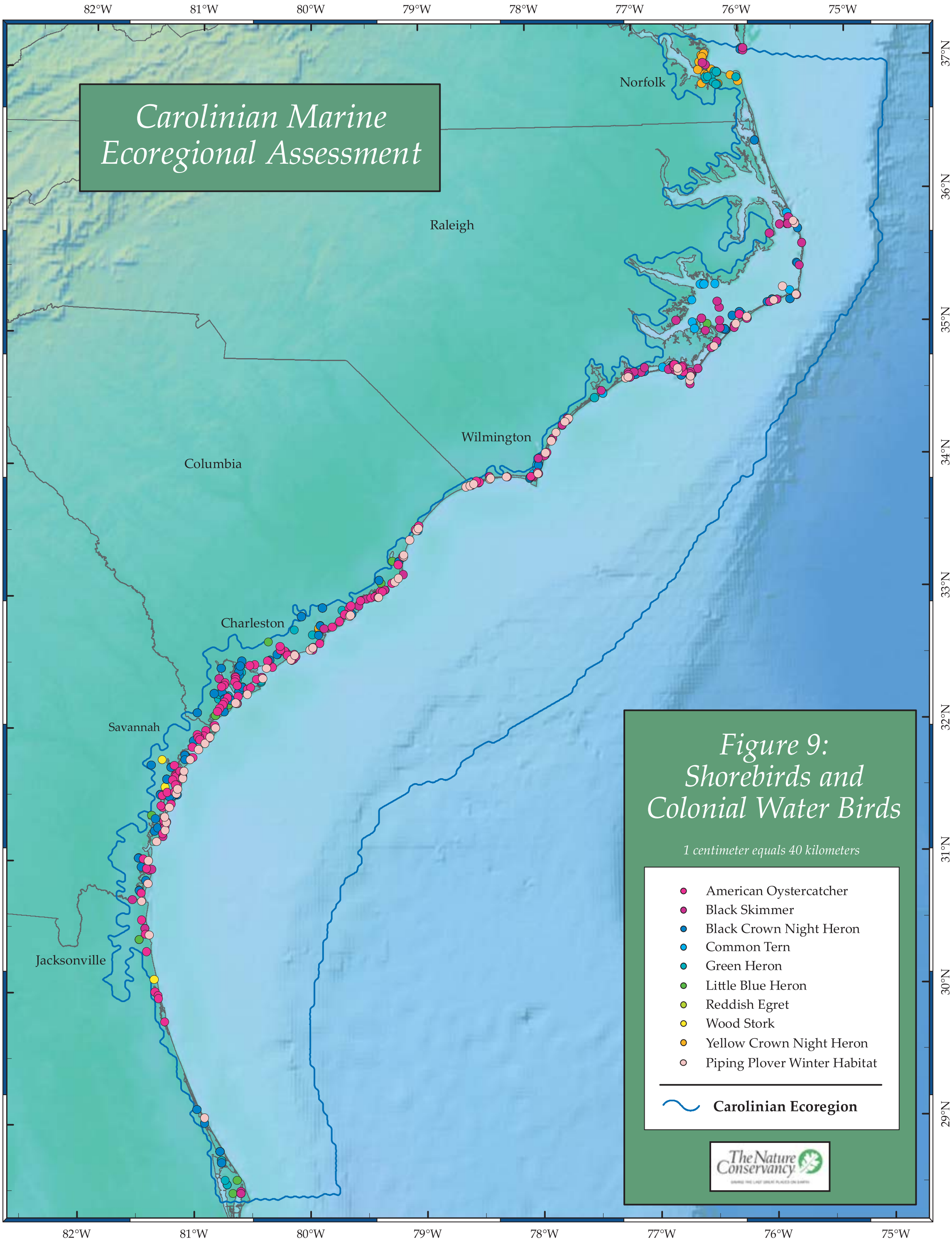


Carolinian Marine Ecoregional Assessment
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Figure 7: Sea Turtle Concentrations
1 centimeter equals 40 kilometers
Very High
High
Medium
Low
Carolinian Ecoregion
The Nature Conservancy

Figure 8

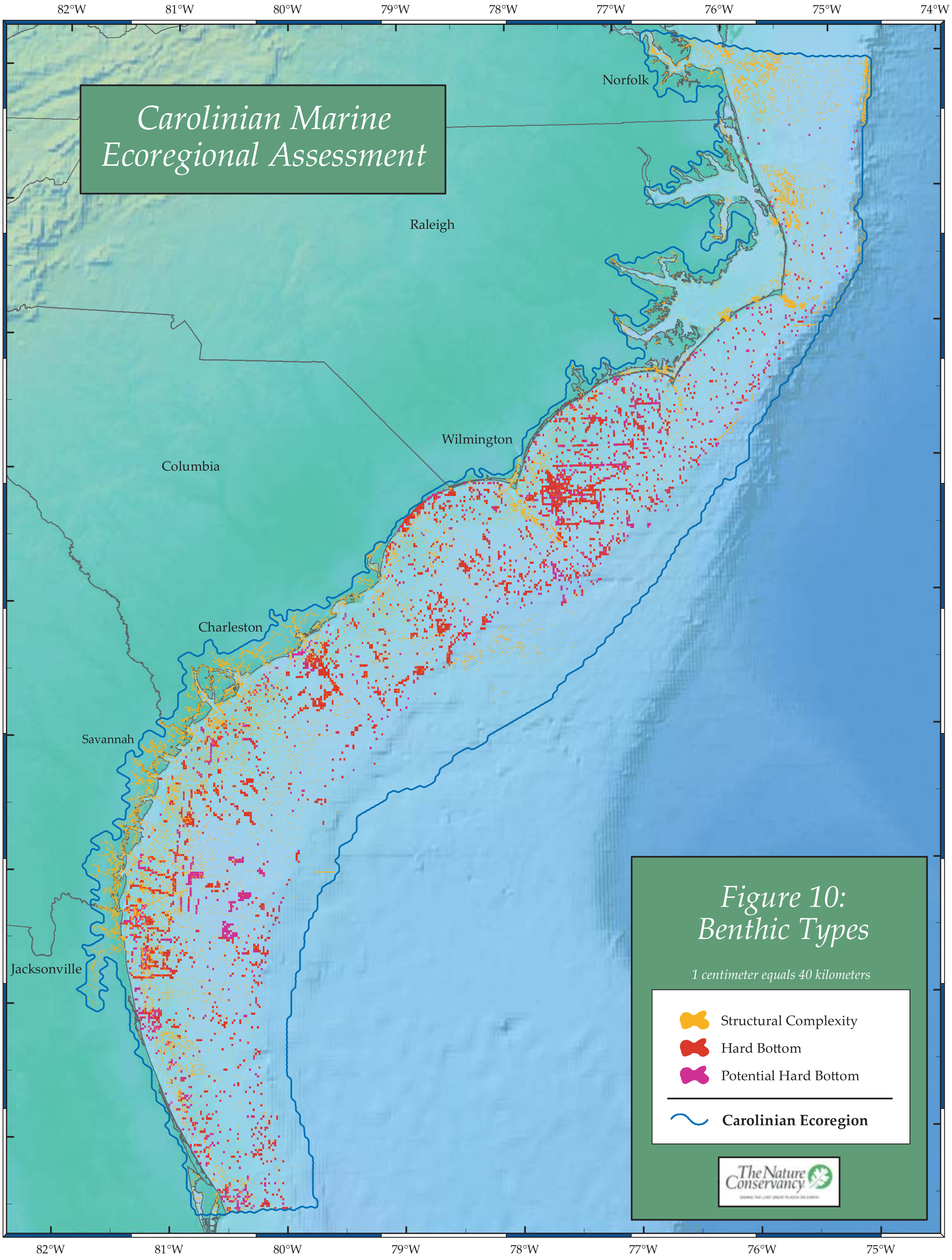


Carolinian Marine Ecoregional Assessment
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Figure 8: Shortnose Sturgeon Habitat
1 centimeter equals 40 kilometers
Tar River
Neuse River
Cape Fear River
Winyah Tributary
Santee System
Cooper River
Savanna River
Ogeechee River
Altamaha River
Carolinian Ecoregion
The Nature Conservancy
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N



Carolinian Marine Ecoregional Assessment
Figure 9: Shorebirds and Colonial Water Birds
1 centimeter equals 40 kilometers
American Oystercatcher
Black Skimmer
Black Crown Night Heron
Common Tern
Green Heron
Little Blue Heron
Reddish Egret
Wood Stork
Yellow Crown Night Heron
Piping Plover Winter Habitat
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

Figure 10


Carolinian Marine Ecoregional Assessment
Figure 10: Benthic Types
1 centimeter equals 40 kilometers
Structural Complexity
Hard Bottom
Potential Hard Bottom
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

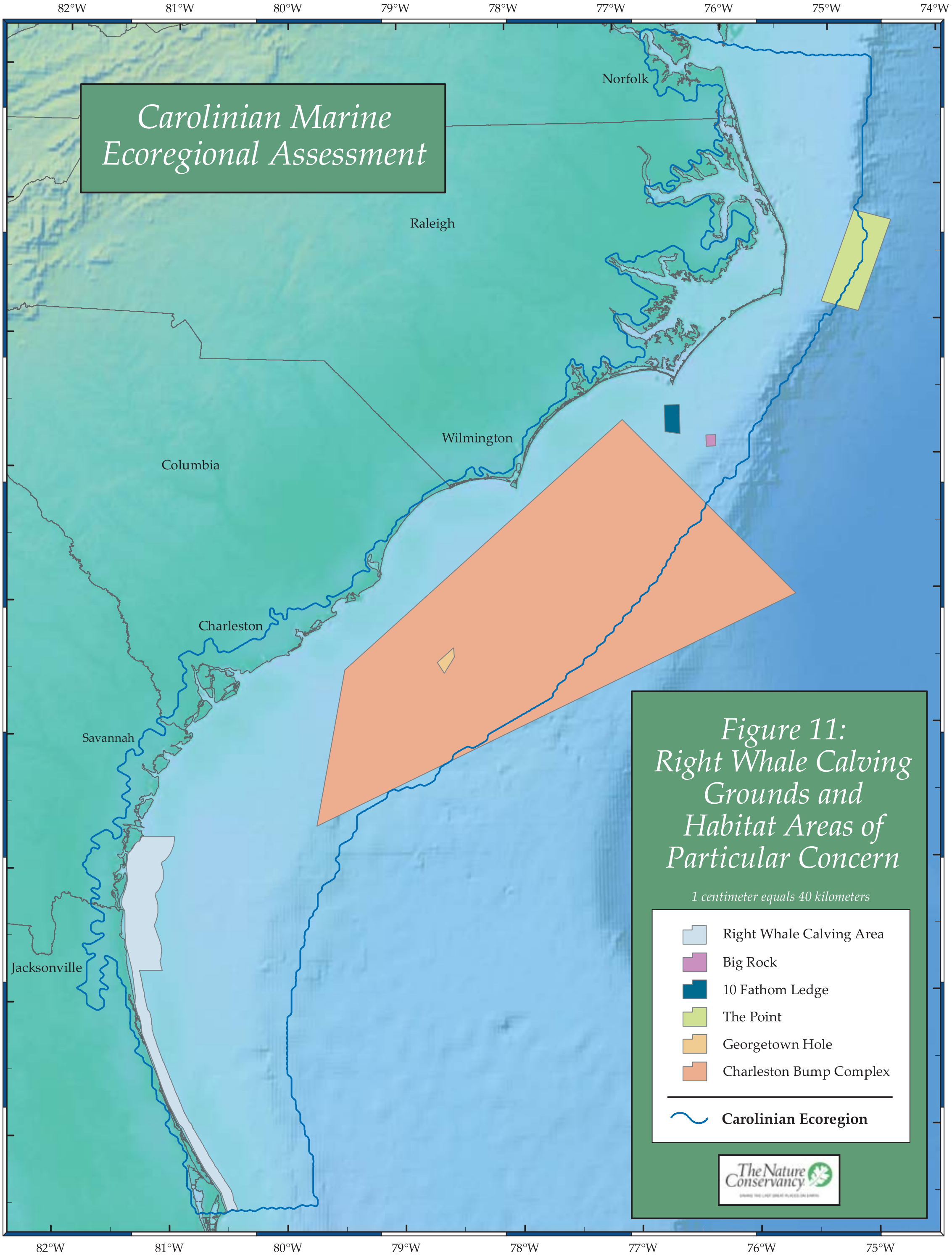
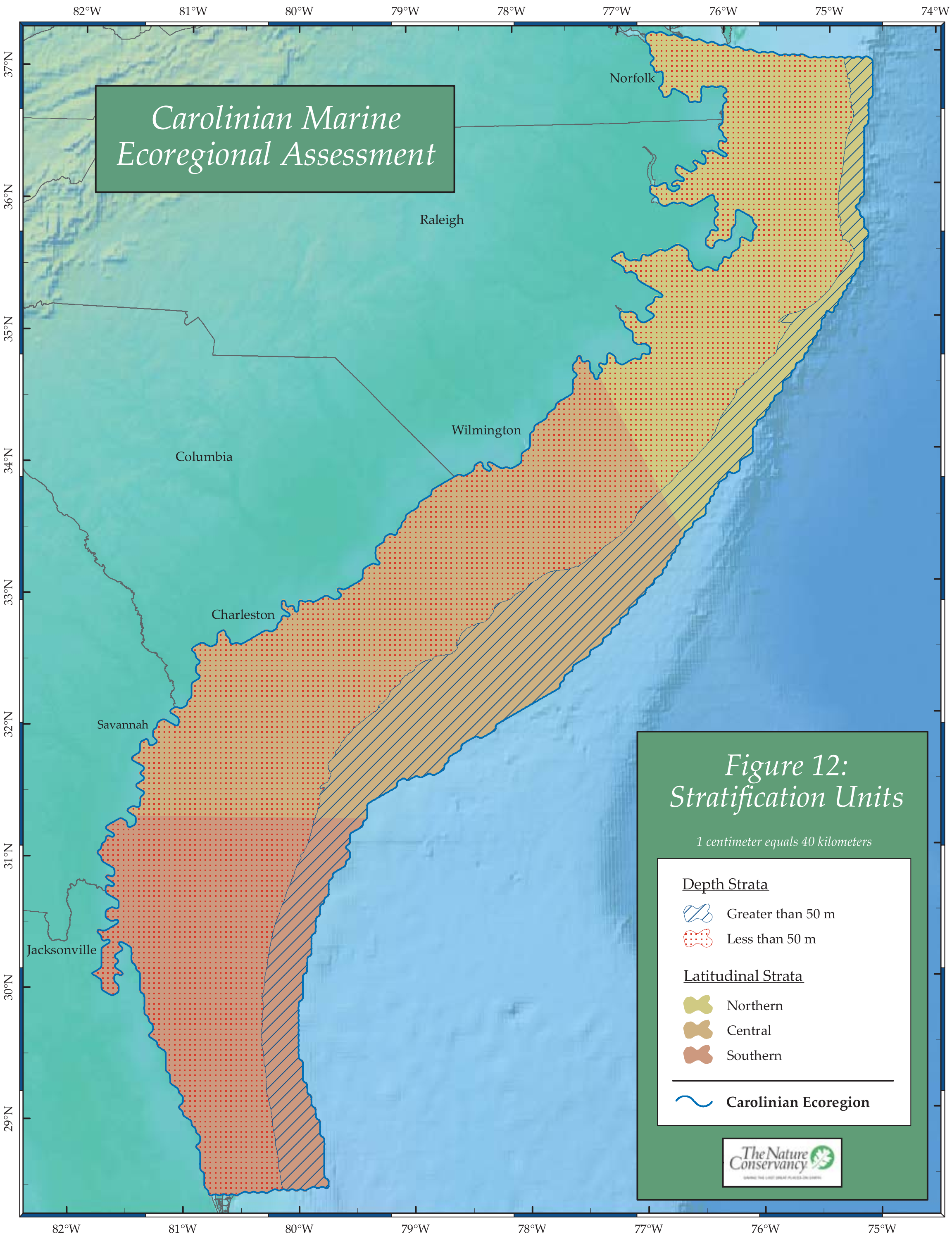

Carolinian Marine Ecoregional Assessment
Figure 11: Right Whale Calving Grounds and Habitat Areas of Particular Concern
1 centimeter equals 40 kilometers
Right Whale Calving Area
Big Rock
10 Fathom Ledge
The Point
Georgetown Hole
Charleston Bump Complex
Carolinian Ecoregion
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N
The Nature Conservancy

Figure 12


82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N
Carolinian Marine Ecoregional Assessment
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Figure 12: Stratification Units
1 centimeter equals 40 kilometers
Depth Strata
Greater than 50 m
Less than 50 m
Latitudinal Strata
Northern
Central
Southern
Carolinian Ecoregion
The Nature Conservancy

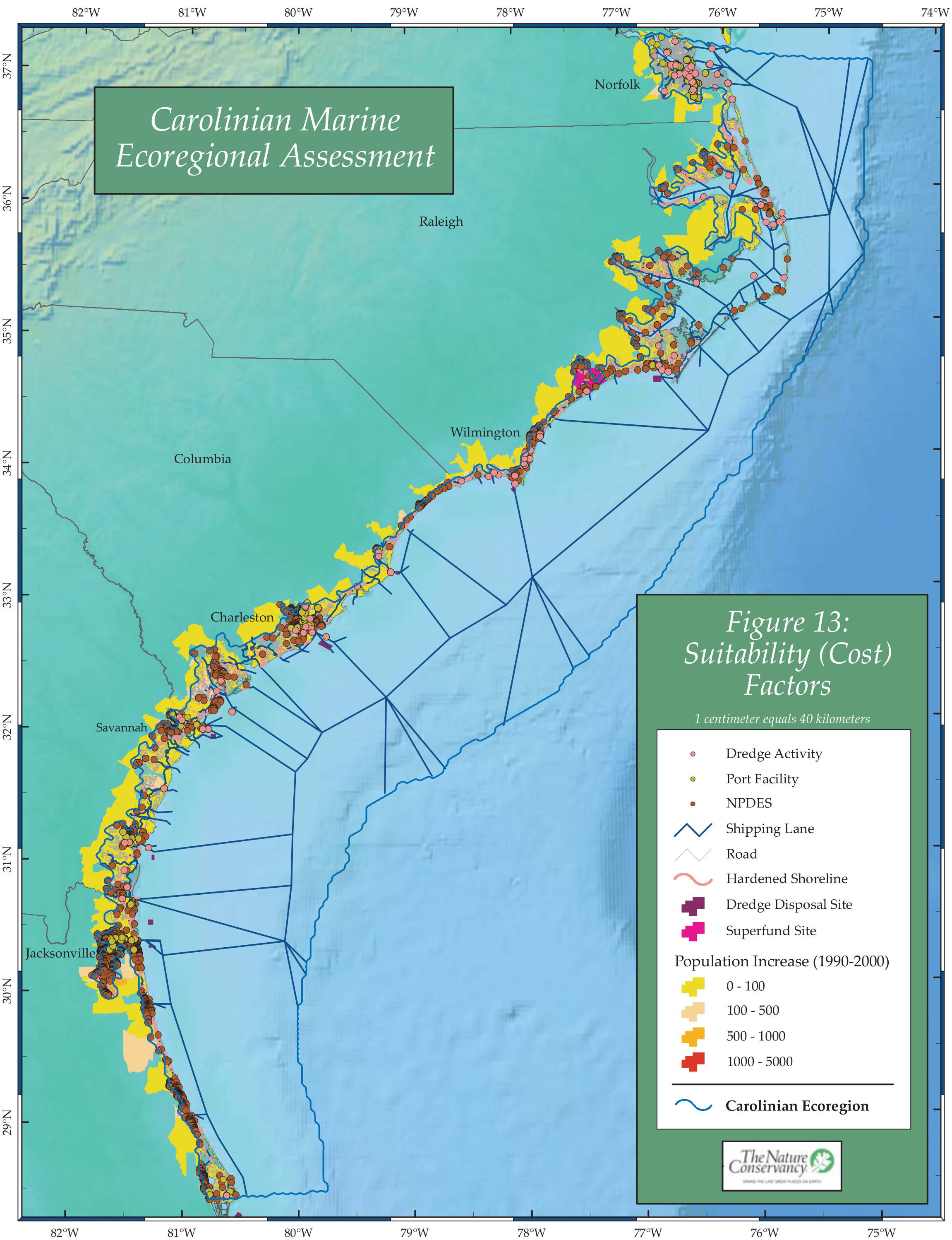
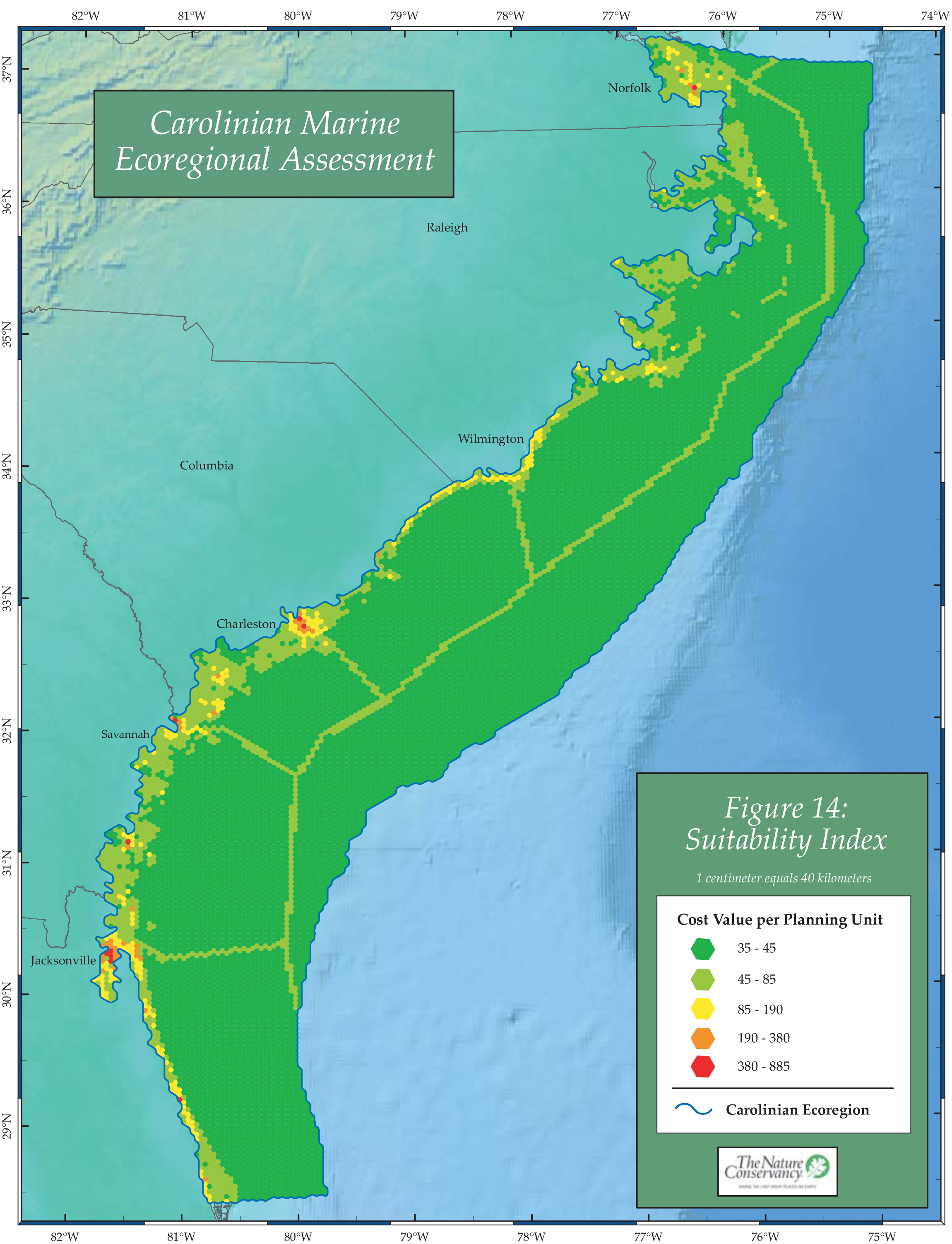

Carolinian Marine
Ecoregional Assessment
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Figure 13:
Suitability (Cost)
Factors
1 centimeter equals 40 kilometers
Dredge Activity
Port Facility
NPDES
Shipping Lane
Road
Hardened Shoreline
Dredge Disposal Site
Superfund Site
Population Increase (1990-2000)
0 - 100
100 - 500
500 - 1000
1000 - 5000
Carolinian Ecoregion
The Nature Conservancy
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

Figure 14



Carolinian Marine Ecoregional Assessment
Figure 14: Suitability Index
1 centimeter equals 40 kilometers
Cost Value per Planning Unit
35 - 45
45 - 85
85 - 190
190 - 380
380 - 885
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

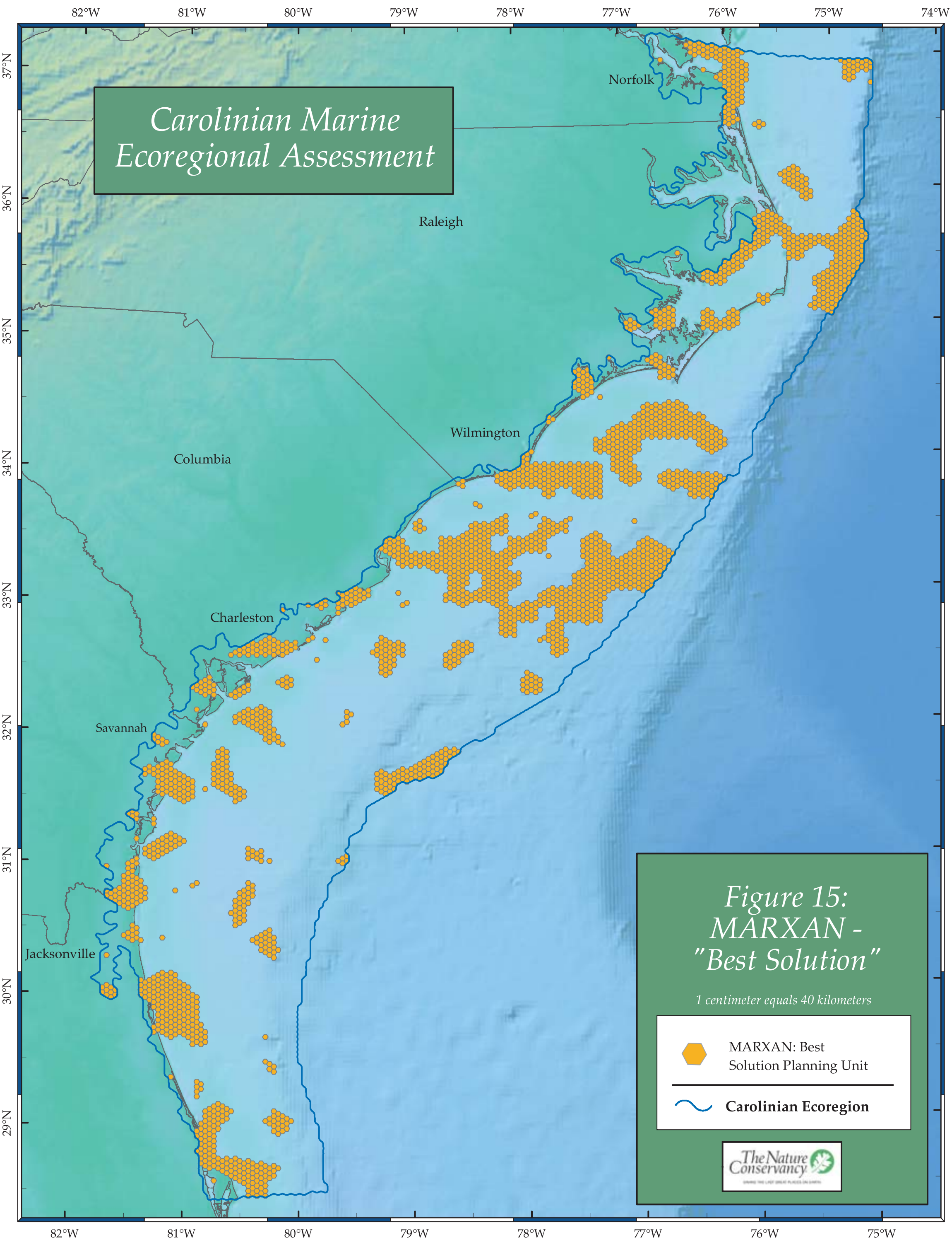
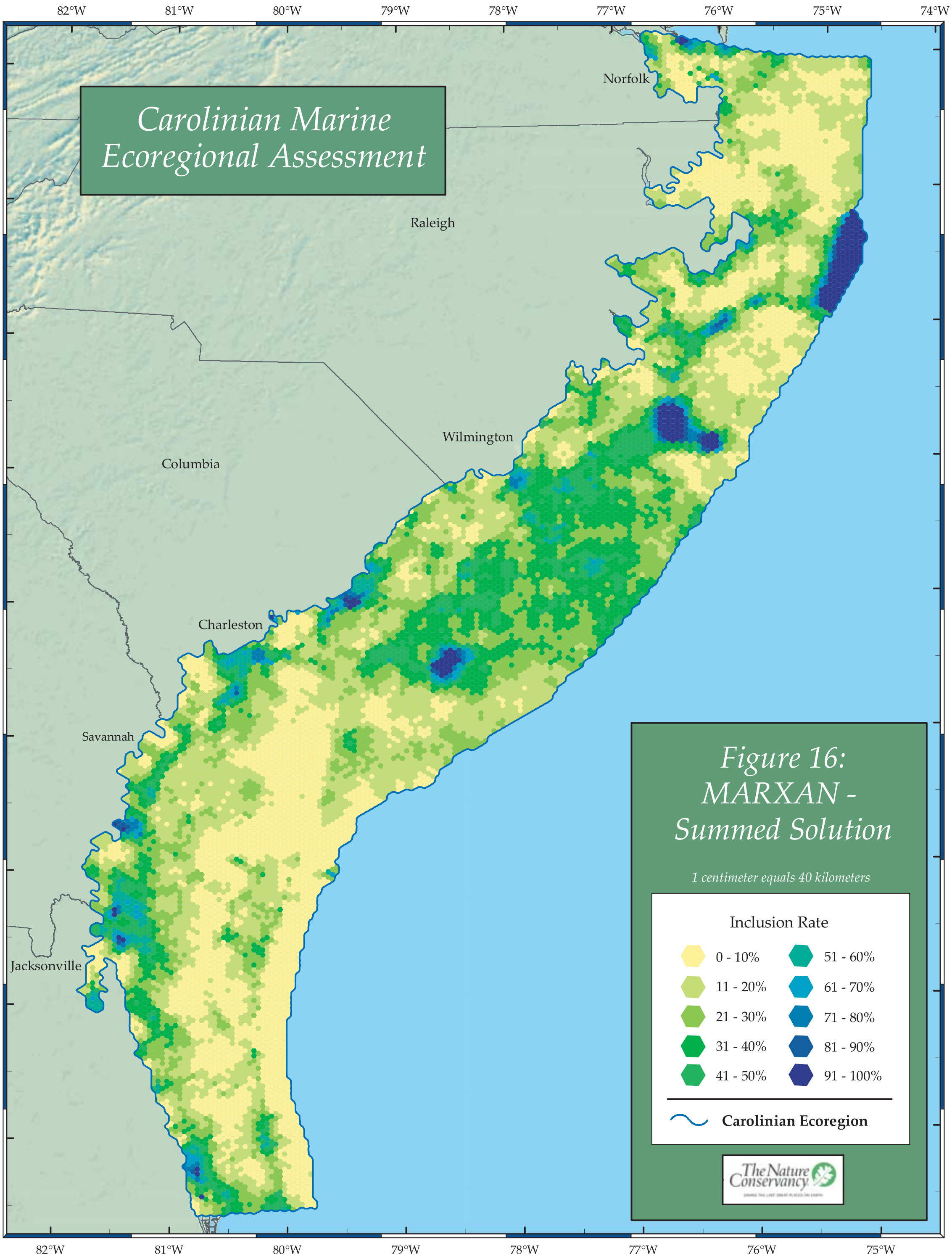
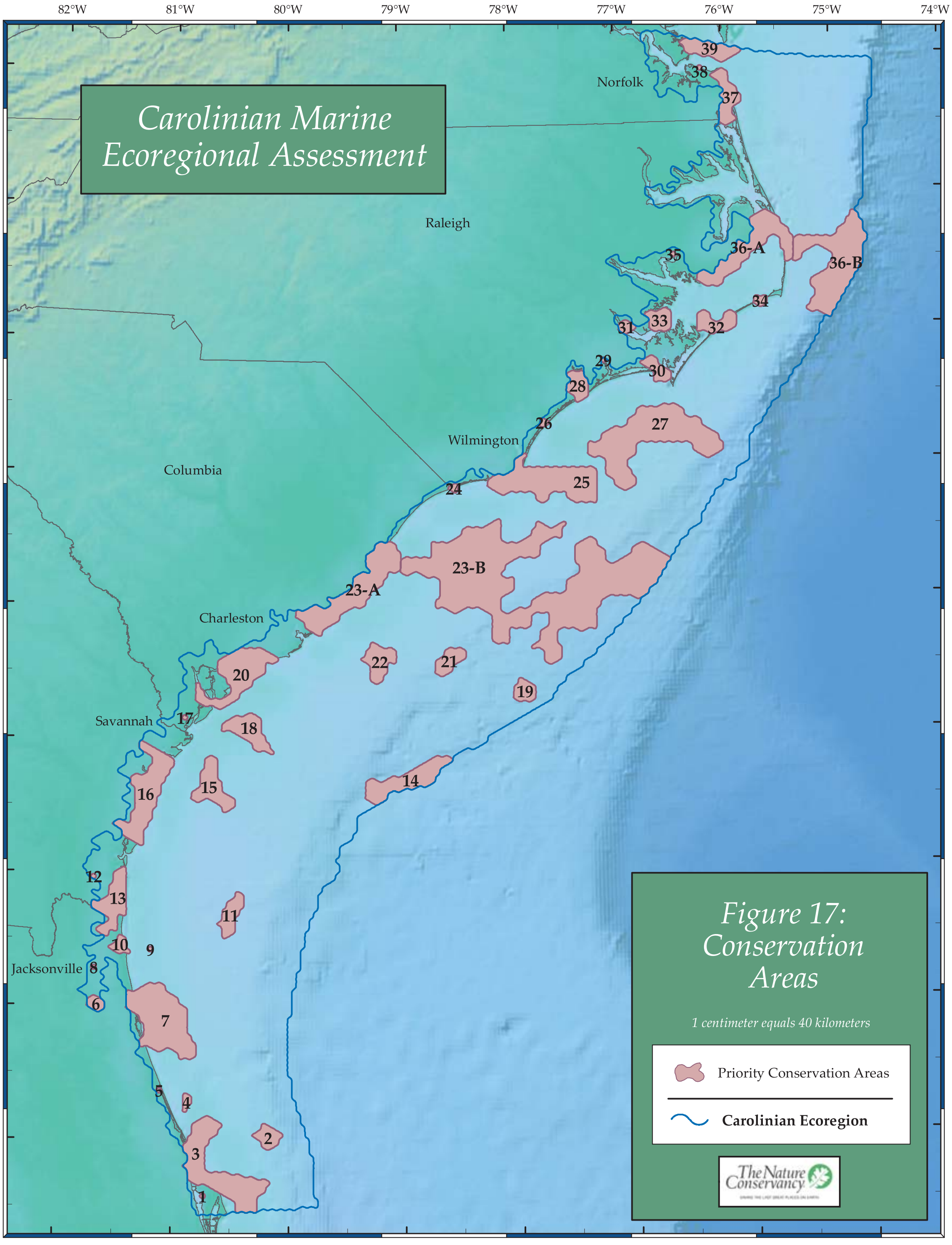

Carolinian Marine
Ecoregional Assessment
Figure 15:
MARXAN -
"Best Solution"
1 centimeter equals 40 kilometers
MARXAN: Best
Solution Planning Unit
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N

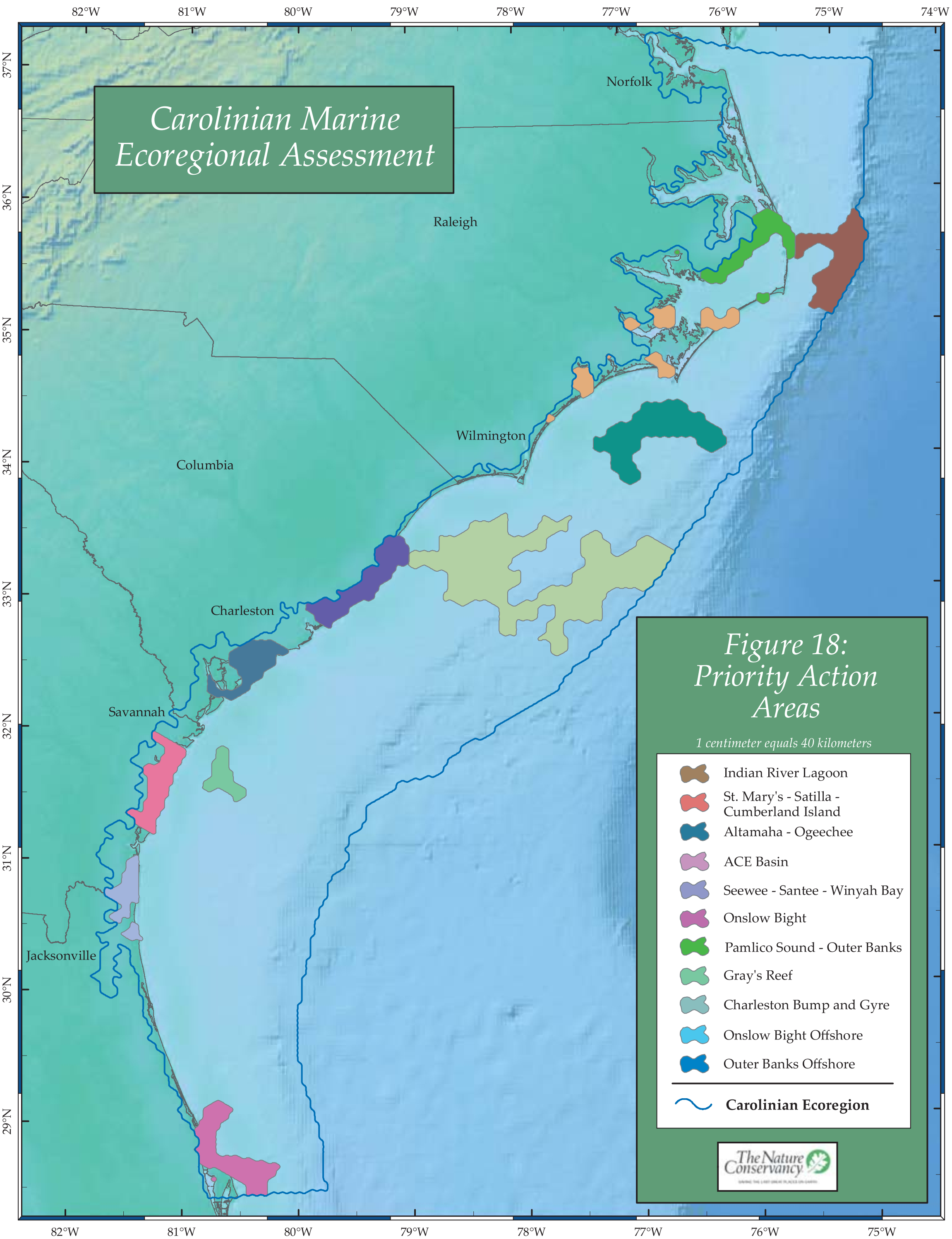
Figure 16


Carolinian Marine Ecoregional Assessment
Figure 16: MARXAN - Summed Solution
1 centimeter equals 40 kilometers
Inclusion Rate
0 - 10%
11 - 20%
21 - 30%
31 - 40%
41 - 50%
51 - 60%
61 - 70%
71 - 80%
81 - 90%
91 - 100%
Carolinian Ecoregion
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N



Carolinian Marine Ecoregional Assessment
Figure 17: Conservation Areas
1 centimeter equals 40 kilometers
Priority Conservation Areas
Carolinian Ecoregion
The Nature Conservancy
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
82°W
81°W
80°W
79°W
78°W
77°W
76°W
75°W
74°W
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
29°N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23-A
23-B
24
25
26
27
28
29
30
31
32
33
34
35
36-A
36-B
37
38
39

Figure 18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Carolinian Marine
Ecoregional Assessment
Norfolk
Raleigh
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Figure 18:
Priority Action
Areas
1 centimeter equals 40 kilometers
Indian River Lagoon
St. Mary's - Satilla - Cumberland Island
Altamaha - Ogeechee
ACE Basin
Seewee - Santee - Winyah Bay
Onslow Bight
Pamlico Sound - Outer Banks
Gray's Reef
Charleston Bump and Gyre
Onslow Bight Offshore
Outer Banks Offshore
Carolinian Ecoregion
The Nature Conservancy

APPENDIX

Appendix 1: The Nature Conservancy's Planning Team Members		
Mike Beck	Senior Scientist, Global Marine Initiative	Santa Cruz, CA
Jeff DeBlieu	Coastal Projects Director, North Carolina Chapter	Kill Devil Hills, NC
Dan Dorfman	Senior Conservation Planner, Global Marine Initiative	Santa Cruz, CA
Patrick Ertel	Conservation Assistant and North Carolina Chapter	Kill Devil Hills, NC
Eric Krueger	South Carolina Chapter	Charleston, SC
Christi Lambert	Georgia Chapter	Darien, GA
Mike Prevost	Sewee to Santee Project Director, South Carolina Chapter	McClellanville, SC
Hallie Stevens	Northeast Florida Program Director, Florida Chapter	Jacksonville, FL
Barry Truitt	Chief Conservation Scientist, Virginia Coast Reserve, Virginia Chapter	Nassawadox, VA
Patrick Halpin	Duke University Geospatial Analysis Program	Durham, NC
Chris Mankoff	Duke University Geospatial Analysis Program	Durham, NC
Kate Eschelbach	Duke University Geospatial Analysis Program	Durham, NC

APPENDIX 2: PEER REVIEW WORKSHOP PARTICIPANTS		
Several workshops were conducted over the course of the assessment process. The following individuals participated or provided separate, individual advice and comment.		
Wendy Allen	Manager North Inlet-Winyah Bay National Estuarine Research Reserve	Georgetown, SC
Henry Ansley	Outer Continental Shelf/Artificial Reef Program Leader Georgia Coastal Resources Division	Brunswick, GA
Sheila Balsdon	Conservation Planner Guana Tolomato Matanzas National Estuarine Research Reserve	St. Augustine, FL
Loren Coen	Shellfish Research Section Manager South Carolina Marine Resources Research Institute	Charleston, SC
Mark Dodd	Sea Turtle Program Coordinator Georgia Coastal Resources Division	Brunswick, GA
Aimee Gaddis	Stewardship Coordinator Sapelo Island National Estuarine Research Reserve	Sapelo Island, GA
Clay George	Wildlife Biologist Georgia Nongame Endangered Wildlife Program	Brunswick, GA
Dorset Hurley	Research Coordinator Sapelo Island National Estuarine Research Reserve	Sapelo Island, GA
Wilson Laney	Assistant South Atlantic Fisheries Coordinator U.S. Fish and Wildlife Service	Raleigh, NC
Roger Pugliese	Senior Fishery Biologist South Atlantic Fishery Management Council	Charleston, SC
Howard Schnabolk	Community-based Restoration Project Manager NOAA Coastal Services Center	Charleston, SC
George Sedberry	Senior Marine Scientist South Carolina Marine Resources Research Institute	Charleston, SC
Mike Street	Habitat Protection Chief North Carolina Division of Marine Fisheries	Morehead City, NC
Jim Sullivan	Regional Projects Coordinator Gray's Reef National Marine Sanctuary	Savannah, GA
Randall Walker	Director University of Georgia Marine Extension Program	Athens, GA
Pace Wilber	Landscape Characterization and Restoration Program Director NOAA Coastal Services Center	Charleston, SC
Spud Woodward	Assistant Director for Marine Fisheries Georgia Coastal Resources Division	Brunswick, GA
TNC STAFF		
Fred Annand	Associate Director for Protection, North Carolina Chapter	Durham, NC
Laura Geselbracht	South Florida Marine Plan Coordinator, Florida Chapter	Fort Lauderdale, FL
Pam Ferral	Director of Science and Stewardship, South Carolina Chapter	Columbia, SC
Sam Pearsall	Director of Science, North Carolina Chapter	Durham, NC
Mark Robertson	State Director, South Carolina Chapter	Columbia, SC

Appendix 3: Conservation Areas with Total Target Concentrations per Area

AREA NUMBER (NAME) 1 Indian River Lagoon			TOTAL AREA 1500 ha	
Seagrass Ecosystems	1117 ha		Yellow Crown Night Heron	1 col
Shellfish Ecosystems	1434 ha		Wood Stork 1	col
Tidal Fresh Marsh	160 ha		Little Blue Heron	1 col
Fresh Marsh	14 ha		Green Heron	1 col
Intertidal Scrub-Shrub	10 ha		Structural Complexity < 50m	18 ha
Sea Turtle Nesting Beaches	1 ha			

AREA NUMBER (NAME) 2			TOTAL AREA 31500 ha	
Hard Bottom < 50m	1192 ha		Structural Complexity < 50m	123 ha
Hard Bottom > 50m	4687 ha		Structural Complexity > 50m	122 ha

AREA NUMBER (NAME) 3 Indian River Lagoon			TOTAL AREA 204000 ha	
Seagrass Ecosystems	20703 ha		Sea Turtle Nesting Beaches	282 ha
Shellfish Ecosystems	22877 ha		Right Whale Calving Grounds	42431 ha
Fine Sand Beach	20 km		Wood Stork 1	col
Coarse Sand Beach	36 km		Little Blue Heron	4 col
Sheltered Tidal Flat	7 km		Green Heron	1 col
Tidal Fresh Marsh	946 ha		Black Crown Night Heron	4 col
Fresh Marsh	2790 ha		Reddish Egret	1 col
Intertidal Scrub-Shrub	2153 ha		Hard Bottom < 50m	30298 ha
Irregularly Flooded Salt Marsh	521 ha		Hard Bottom > 50m	243 ha
Regularly Flooded Salt Marsh	3 ha		Structural Complexity < 50m	2018 ha

AREA NUMBER (NAME) 4			TOTAL AREA 9000 ha	
Sea Turtle Nesting Beaches	5 ha		Hard Bottom < 50m	3230 ha
Right Whale Calving Grounds	154 ha		Structural Complexity < 50m	218 ha

AREA NUMBER (NAME) 5			TOTAL AREA 1500 ha	
Fine Sand Beach	1 km		Irregularly Flooded Salt Marsh	126 ha
Forested Wetlands	31 ha		Salt Marsh with Variable Flooding	271 ha

AREA NUMBER (NAME) 6			TOTAL AREA 15000 ha	
Tidal Fresh Marsh	3 ha		Shortnose Sturgeon Habitat	4677 ha
Fresh Marsh	515 ha		Structural Complexity < 50m	125 ha
Irregularly Flooded Salt Marsh	3 ha			

AREA NUMBER (NAME) 7			TOTAL AREA 223500 ha	
Shellfish Ecosystems	1875 ha		Salt Marsh with Variable Flooding	448 ha
Fine Sand Beach	11 km		Sea Turtle Nesting Beaches	212 ha
Coarse Sand Beach	24 km		Right Whale Calving Grounds	42081 ha
Fresh Marsh	300 ha		American Oystercatcher	8 ind
Intertidal Scrub-Shrub	44 ha		Wood Stork 1	col
Forested Wetlands	35 ha		Hard Bottom < 50m	29349 ha
Irregularly Flooded Salt Marsh	3638 ha		Structural Complexity < 50m	3927 ha
Regularly Flooded Salt Marsh	99 ha			

AREA NUMBER (NAME) 8			TOTAL AREA 1500 ha	
Shortnose Sturgeon Habitat	1374 ha		Structural Complexity < 50m	118 ha

AREA NUMBER (NAME) 9			TOTAL AREA 1500 ha	
Right Whale Calving Grounds	1499 ha		Structural Complexity < 50m	71 ha
Hard Bottom < 50m	1061 ha			

AREA NUMBER (NAME)			TOTAL AREA	

10 St. Mary's-Satilla-Cumberland Island Estuarine Complex			16500 ha	
Shellfish Ecosystems	3927 ha		Shortnose Sturgeon Habitat	2009 ha
Fine Sand Beach	30 km		American Oystercatcher	16 ind
Fresh Marsh	19 ha		Piping Plover	2318 ha
Intertidal Scrub-Shrub	1 ha		Wood Stork 1	col
Forested Wetlands	37 ha		Little Blue Heron	2 col
Irregularly Flooded Salt Marsh	5183 ha		Common Tern 1	col
Regularly Flooded Salt Marsh	192 ha		Black Skimmer	2 col
Sea Turtle Nesting Beaches	6 ha		Hard Bottom < 50m	1 ha
Right Whale Calving Grounds	1292 ha		Structural Complexity < 50m	1019 ha

AREA NUMBER (NAME) 11			TOTAL AREA 43500 ha	
Hard Bottom < 50m	13757 ha		Structural Complexity < 50m	233 ha

AREA NUMBER (NAME) 12			TOTAL AREA 1500 ha	
Tidal Fresh Marsh	20 ha		Forested Wetlands	1 ha
Fresh Marsh	22 ha		Irregularly Flooded Salt Marsh	464 ha
Intertidal Scrub-Shrub	129 ha		Structural Complexity < 50m	55 ha

AREA NUMBER (NAME) 13 St. Mary's-Satilla-Cumberland Island Estuarine Complex			TOTAL AREA 85500 ha	
Shellfish Ecosystems	4072 ha		Sea Turtle Nesting Beaches	50 ha
Fine Sand Beach	47 km		Right Whale Calving Grounds	4709 ha
Coarse Sand Beach	2 km		American Oystercatcher	233 ind
Exposed Tidal Flat	3 km		Piping Plover	2197 ha
Tidal Fresh Marsh	158 ha		Little Blue Heron	3 col
Fresh Marsh	412 ha		Green Heron	1 col
Intertidal Scrub-Shrub	239 ha		Black Skimmer	2 col
Forested Wetlands	40 ha		Black Crown Night Heron	3 col
Irregularly Flooded Salt Marsh	6574 ha		Hard Bottom < 50m	215 ha
Regularly Flooded Salt Marsh	17975 ha		Structural Complexity < 50m	3920 ha

AREA NUMBER (NAME) 14			TOTAL AREA 109500 ha	
HAPC - Charleston Bump/Gyre	77554 ha			

AREA NUMBER (NAME) 15			TOTAL AREA 76500 ha	
Hard Bottom < 50m	13538 ha		Structural Complexity < 50m	1209 ha

AREA NUMBER (NAME) 16 Altamaha-Ogeechee Estuarine Complex			TOTAL AREA 159000 ha	
Shellfish Ecosystems	8000 ha		American Oystercatcher	531 ind
Fine Sand Beach	97 km		Piping Plover	3497 ha
Tidal Fresh Marsh	2399 ha		Yellow Crown Night Heron	1 col
Fresh Marsh	2527 ha		Wood Stork 5	col
Intertidal Scrub-Shrub	835 ha		Little Blue Heron	10 col
Forested Wetlands	211 ha		Green Heron	2 col
Irregularly Flooded Salt Marsh	15115 ha		Black Skimmer	1 col
Regularly Flooded Salt Marsh	44519 ha		Black Crown Night Heron	17 col
Sea Turtle Nesting Beaches	101 ha		Hard Bottom < 50m	581 ha
Right Whale Calving Grounds	1844 ha		Structural Complexity < 50m	7041 ha
Shortnose Sturgeon Habitat	9208 ha			

AREA NUMBER (NAME) 17			TOTAL AREA 1500 ha	
Shellfish Ecosystems	1018 ha		Regularly Flooded Salt Marsh	750 ha
Fresh Marsh	1 ha		Structural Complexity < 50m	44 ha
Irregularly Flooded Salt Marsh	110 ha			

AREA NUMBER (NAME) 18			TOTAL AREA 69000 ha	
Hard Bottom < 50m	9548 ha		Structural Complexity < 50m	1728 ha

AREA NUMBER (NAME) 19			TOTAL AREA 28500 ha	
HAPC - Charleston Bump/Gyre	28500 ha			

AREA NUMBER (NAME)			TOTAL AREA	

20 ACE Basin Estuarine Complex		147000 ha	
Shellfish Ecosystems	69309 ha	Sea Turtle Nesting Beaches	50 ha
Fine Sand Beach	66 km	American Oystercatcher	440 ind
Coarse Sand Beach	2 km	Piping Plover	870 ha
Sheltered Tidal Flat with Oysters	1 km	Yellow Crown Night Heron	6 col
Exposed Tidal Flat	5 km	Little Blue Heron	6 col
Tidal Fresh Marsh	166 ha	Green Heron	8 col
Fresh Marsh	1366 ha	Common Tern	1 col
Intertidal Scrub-Shrub	244 ha	Black Skimmer	3 col
Forested Wetlands	4 ha	Black Crown Night Heron	7 col
Irregularly Flooded Salt Marsh	6341 ha	Hard Bottom < 50m	92 ha
Regularly Flooded Salt Marsh	28538 ha	Structural Complexity < 50m	6571 ha
Salt Marsh with Variable Flooding	1501 ha		

AREA NUMBER (NAME) 21		TOTAL AREA 37500 ha	
Hard Bottom < 50m	2826 ha	Structural Complexity > 50m	211 ha
Hard Bottom > 50m	2594 ha	HAPC - Charleston Bump/Gyre	37500 ha
Structural Complexity < 50m	258 ha	HAPC - Other	13009 ha

AREA NUMBER (NAME) 22		TOTAL AREA 57000 ha	
Hard Bottom < 50m	6323 ha	HAPC - Charleston Bump/Gyre	55185 ha
Structural Complexity < 50m	545 ha		

AREA NUMBER (NAME) 23-A Sewee-Santee-Winyah Bay Estuarine Complex		TOTAL AREA 199500 ha	
Shellfish Ecosystems	59509 ha	Shortnose Sturgeon Habitat	5337 ha
Fine Sand Beach	91 km	American Oystercatcher	1631 ind
Coarse Sand Beach	21 km	Piping Plover	1763 ha
Sheltered Tidal Flat with Oysters	1 km	Yellow Crown Night Heron	2 col
Exposed Tidal Flat	3 km	Wood Stork	1 col
Tidal Fresh Marsh	1411 ha	Little Blue Heron	5 col
Fresh Marsh	11172 ha	Green Heron	3 col
Intertidal Scrub-Shrub	746 ha	Common Tern	3 col
Forested Wetlands	172 ha	Black Skimmer	8 col
Irregularly Flooded Salt Marsh	4863 ha	Black Crown Night Heron	4 col
Regularly Flooded Salt Marsh	28412 ha	Hard Bottom < 50m	4745 ha
Sea Turtle Nesting Beaches	85 ha	Structural Complexity < 50m	5147 ha

AREA NUMBER (NAME) 23-B Charleston Bump and Gyre Complex		TOTAL AREA 1021500 ha	
Hard Bottom < 50m	56961 ha	Structural Complexity > 50m	834 ha
Hard Bottom > 50m	14464 ha	HAPC - Charleston Bump/Gyre	849388 ha
Structural Complexity < 50m	4736 ha		

AREA NUMBER (NAME) 24		TOTAL AREA 4500 ha	
Shellfish Ecosystems	353 ha	Irregularly Flooded Salt Marsh	82 ha
Fine Sand Beach	11 km	Regularly Flooded Salt Marsh	808 ha
Coarse Sand Beach	2 km	Sea Turtle Nesting Beaches	2 ha
Exposed Tidal Flat	1 km	American Oystercatcher	10 ind
Tidal Fresh Marsh	1 ha	Piping Plover	229 ha
Intertidal Scrub-Shrub	9 ha	Hard Bottom < 50m	833 ha
Forested Wetlands	2 ha	Structural Complexity < 50m	97 ha

AREA NUMBER (NAME) 25		TOTAL AREA 210000 ha	
Shellfish Ecosystems	457 ha	Shortnose Sturgeon Habitat	6174 ha
Fine Sand Beach	20 km	American Oystercatcher	340 ind
Coarse Sand Beach	44 km	Piping Plover	1367 ha
Tidal Fresh Marsh	86 ha	Little Blue Heron	4 col
Fresh Marsh	468 ha	Green Heron	2 col
Intertidal Scrub-Shrub	215 ha	Common Tern	6 col
Forested Wetlands	36 ha	Black Skimmer	3 col
Irregularly Flooded Salt Marsh	465 ha	Black Crown Night Heron	4 col
Regularly Flooded Salt Marsh	3749 ha	Hard Bottom < 50m	65361 ha
Salt Marsh with Variable Flooding	0 ha	Structural Complexity < 50m	3043 ha
Sea Turtle Nesting Beaches	15 ha	HAPC - Charleston Bump/Gyre	93974 ha

AREA NUMBER (NAME) 26 Onslow Bight Estuarine Complex		TOTAL AREA 4500 ha	
Shellfish Ecosystems	1736 ha	Sea Turtle Nesting Beaches	2 ha
Coarse Sand Beach	7 km	Piping Plover	472 ha
Regularly Flooded Salt Marsh	1422 ha	Common Tern	3 col
Intertidal Scrub-Shrub	9 ha	Black Skimmer	3 col
Irregularly Flooded Salt Marsh	13 ha	Structural Complexity < 50m	8 ha
Fine Sand Beach	0 km		

AREA NUMBER (NAME) 27 Onslow Bight Ocean Complex		TOTAL AREA 327000 ha	
Hard Bottom < 50m	50066 ha	Structural Complexity > 50m	76 ha
Hard Bottom > 50m	2557 ha	HAPC - Charleston Bump/Gyre	123447 ha
Structural Complexity < 50m	1184 ha	HAPC - Ten Fathom Ledge/Big Rock	35463 ha

AREA NUMBER (NAME) 28 Onslow Bight Estuarine Complex		TOTAL AREA 36000 ha	
Shellfish Ecosystems	8779 ha	Sea Turtle Nesting Beaches	3 ha
Coarse Sand Beach	23 km	Little Blue Heron	1 col
Exposed Tidal Flat	1 km	Green Heron	2 col
Fresh Marsh	191 ha	Common Tern 2	col
Intertidal Scrub-Shrub	713 ha	Black Skimmer	1 col
Forested Wetlands	21 ha	Hard Bottom < 50m	1132 ha
Irregularly Flooded Salt Marsh	290 ha	Structural Complexity < 50m	183 ha
Regularly Flooded Salt Marsh	675 ha		

AREA NUMBER (NAME) 29 Onslow Bight Estuarine Complex		TOTAL AREA 1500 ha	
Tidal Fresh Marsh	81 ha	Regularly Flooded Salt Marsh	2 ha
Irregularly Flooded Salt Marsh	84 ha		

AREA NUMBER (NAME) 30 Onslow Bight Estuarine Complex		TOTAL AREA 28500 ha	
Seagrass Ecosystems	586 ha	Piping Plover	1258 ha
Shellfish Ecosystems	8825 ha	Yellow Crown Night Heron	2 col
Coarse Sand Beach	42 km	Little Blue Heron	3 col
Fresh Marsh	19 ha	Green Heron	3 col
Intertidal Scrub-Shrub	167 ha	Common Tern	10 col
Irregularly Flooded Salt Marsh	1003 ha	Black Skimmer	5 col
Regularly Flooded Salt Marsh	1778 ha	Black Crown Night Heron	6 col
Sea Turtle Nesting Beaches	4 ha	Hard Bottom < 50m	654 ha
American Oystercatcher	81 ind	Structural Complexity < 50m	1098 ha

AREA NUMBER (NAME) 31 Onslow Bight Estuarine Complex		TOTAL AREA 12000 ha	
Seagrass Ecosystems	4 ha	Irregularly Flooded Salt Marsh	421 ha
Coarse Sand Beach	1 km	Shortnose Sturgeon Habitat	5043 ha
Fresh Marsh	10 ha	Structural Complexity < 50m	151 ha
Intertidal Scrub-Shrub	21 ha		

AREA NUMBER (NAME) 32 Onslow Bight Estuarine Complex		TOTAL AREA 45000 ha	
Seagrass Ecosystems	3450 ha	Piping Plover	5456 ha
Shellfish Ecosystems	10536 ha	Little Blue Heron	2 col
Coarse Sand Beach	61 km	Common Tern	8 col
Intertidal Scrub-Shrub	310 ha	Black Skimmer	6 col
Fine Sand Beach	0 km	Black Crown Night Heron	2 col
Irregularly Flooded Salt Marsh	765 ha	Hard Bottom < 50m	516 ha
Regularly Flooded Salt Marsh	486 ha	Structural Complexity < 50m	1554 ha
Sea Turtle Nesting Beaches	28 ha		

AREA NUMBER (NAME) 33 Onslow Bight Estuarine Complex		TOTAL AREA 33000 ha	
Shellfish Ecosystems	2 ha	Shortnose Sturgeon Habitat	11159 ha
Fresh Marsh	115 ha	Common Tern 1	col
Intertidal Scrub-Shrub	188 ha	Black Skimmer	1 col
Forested Wetlands	14 ha	Structural Complexity < 50m	213 ha
Irregularly Flooded Salt Marsh	1974 ha		

AREA NUMBER (NAME)		TOTAL AREA	

34 Pamlico Sound-Outer Banks Estuarine Complex		9000 ha	
Seagrass Ecosystems	1387 ha	Little Blue Heron	1 col
Coarse Sand Beach	23 km	Common Tern	3 col
Intertidal Scrub-Shrub	76 ha	Black Skimmer	3 col
Irregularly Flooded Salt Marsh	151 ha	Black Crown Night Heron	1 col
Regularly Flooded Salt Marsh	57 ha	Hard Bottom < 50m	9 ha
Sea Turtle Nesting Beaches	10 ha	Structural Complexity < 50m	579 ha
Piping Plover	1049 ha		

AREA NUMBER (NAME) 35 Pamlico Sound-Outer Banks Estuarine Complex		TOTAL AREA 1500 ha	
Intertidal Scrub-Shrub	10 ha	Structural Complexity < 50m	71 ha
Irregularly Flooded Salt Marsh	440 ha		

AREA NUMBER (NAME) 36-A Pamlico Sound-Outer Banks Estuarine Complex		TOTAL AREA 150000 ha	
Seagrass Ecosystems	8103 ha	Sea Turtle Nesting Beaches	15 ha
Shellfish Ecosystems	4053 ha	Piping Plover	671 ha
Coarse Sand Beach	52 km	Yellow Crown Night Heron	1 col
Fresh Marsh	925 ha	Little Blue Heron	5 col
Intertidal Scrub-Shrub	3211 ha	Common Tern	8 col
Forested Wetlands	1 ha	Black Skimmer	9 col
Irregularly Flooded Salt Marsh	12423 ha	Black Crown Night Heron	6 col
Regularly Flooded Salt Marsh	250 ha	Hard Bottom < 50m	644 ha
Salt Marsh with Variable Flooding	119 ha	Structural Complexity < 50m	1073 ha

AREA NUMBER (NAME) 36-B Outer Banks Ocean Complex		TOTAL AREA 246000 ha	
Hard Bottom < 50m	3452 ha	Structural Complexity > 50m	1586 ha
Hard Bottom > 50m	2015 ha	HAPC - The Point/Hatteras Corner	124467 ha
Structural Complexity < 50m	2584 ha		

AREA NUMBER (NAME) 37		TOTAL AREA 57000 ha	
Seagrass Ecosystems	44 ha	Forested Wetlands	12 ha
Fine Sand Beach	3 km	Irregularly Flooded Salt Marsh	4926 ha
Coarse Sand Beach	31 km	Regularly Flooded Salt Marsh	3 ha
Sheltered Tidal Flat	3 km	Yellow Crown Night Heron	3 col
Tidal Fresh Marsh	75 ha	Green Heron	1 col
Fresh Marsh	253 ha	Structural Complexity < 50m	994 ha
Intertidal Scrub-Shrub	30 ha		

AREA NUMBER (NAME) 38		TOTAL AREA 1500 ha	
Coarse Sand Beach	3 km	Green Heron	1 col
Irregularly Flooded Salt Marsh	13 ha	Structural Complexity < 50m	15 ha
Yellow Crown Night Heron	3 col		

AREA NUMBER (NAME) 39		TOTAL AREA 55500 ha	
Seagrass Ecosystems	866 ha	Regularly Flooded Salt Marsh	97 ha
Mixed Sand and Gravel Beach	1 km	Salt Marsh with Variable Flooding	890 ha
Fine Sand Beach	13 km	Yellow Crown Night Heron	3 col
Coarse Sand Beach	12 km	Little Blue Heron	2 col
Tidal Fresh Marsh	17 ha	Green Heron	2 col
Fresh Marsh	5 ha	Common Tern 5	col
Intertidal Scrub-Shrub	28 ha	Black Skimmer	3 col
Forested Wetlands	70 ha	Black Crown Night Heron	3 col
Irregularly Flooded Salt Marsh	1174 ha	Structural Complexity < 50m	2680 ha

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Outside back cover, left to right: Piping Plover © Michael Halminski; Marsh, © TNC Staff; Blue Crab © VIMS/ Submerged Aquatic Vegetation Program; Eastern Oysters © Michael Halminski

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Inside back cover: Nesting site © Michael Halminski

The Nature Conservancy

SAVING THE LAST GREAT PLACES ON EARTH

The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.