I. INTRODUCTION

A. North Carolina Environmental Setting

North Carolina (N.C.) lies between 33.5° and 37° north latitude and between 75° and 84.5° west longitude midway along the U.S. Eastern seaboard (Figure 2). The total area of the State is 52,669 square miles (136,524 km^2), of which 48,843 square miles (127,278 km^2) are land and 3,826 square miles (9,246 km^2) are water (State Library of North Carolina 2008). The state is divided into three distinct topographical regions (the Coastal Plain, the Piedmont Plateau, and the Blue Ridge/Appalachian Mountains) and two unique biogeographical provinces (the Virginian and Carolinian) (Figure 2).

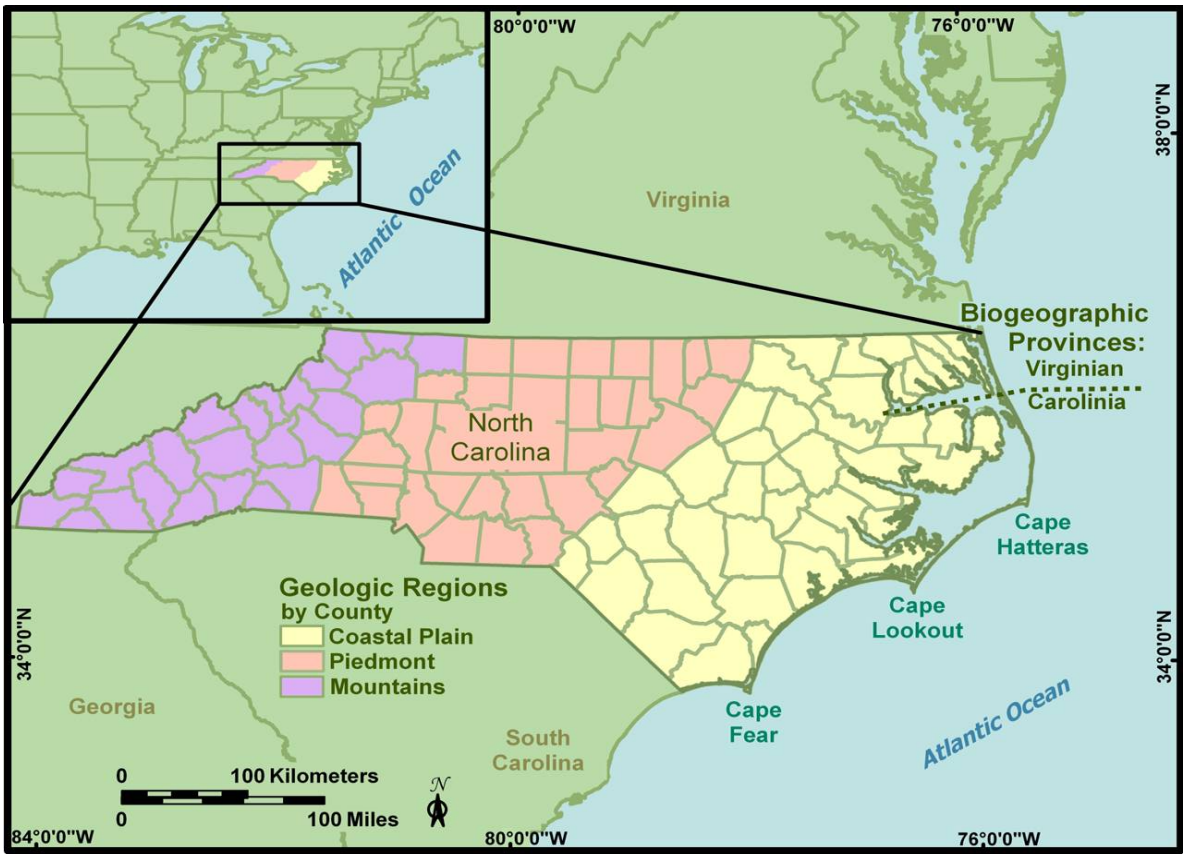

Figure 2: North Carolina geological regions and biogeographical provinces

1. The Coastal Plain

North Carolina's coastal plain juts out from the East Coast of the United States into the Atlantic Ocean and the Gulf Stream. It runs from Virginia to South Carolina and extends inward approximately 100 miles, where the land rises imperceptibly into the Piedmont or foothills. The land and water areas of the coastal plain comprise nearly half the area of the State. The coastline is further subdivided into three distinct regions (Northern, Central and Southern) based on geomorphological and ecological features (Figure 3). Each region has a unique geologic

framework that results in distinctive types of barrier islands, inlets and estuaries influenced by different wave and tidal processes (Pilkey et al. 1998). The underlying geology leads to distinctive coastal habitat types with different biological and anthropogenic influences.

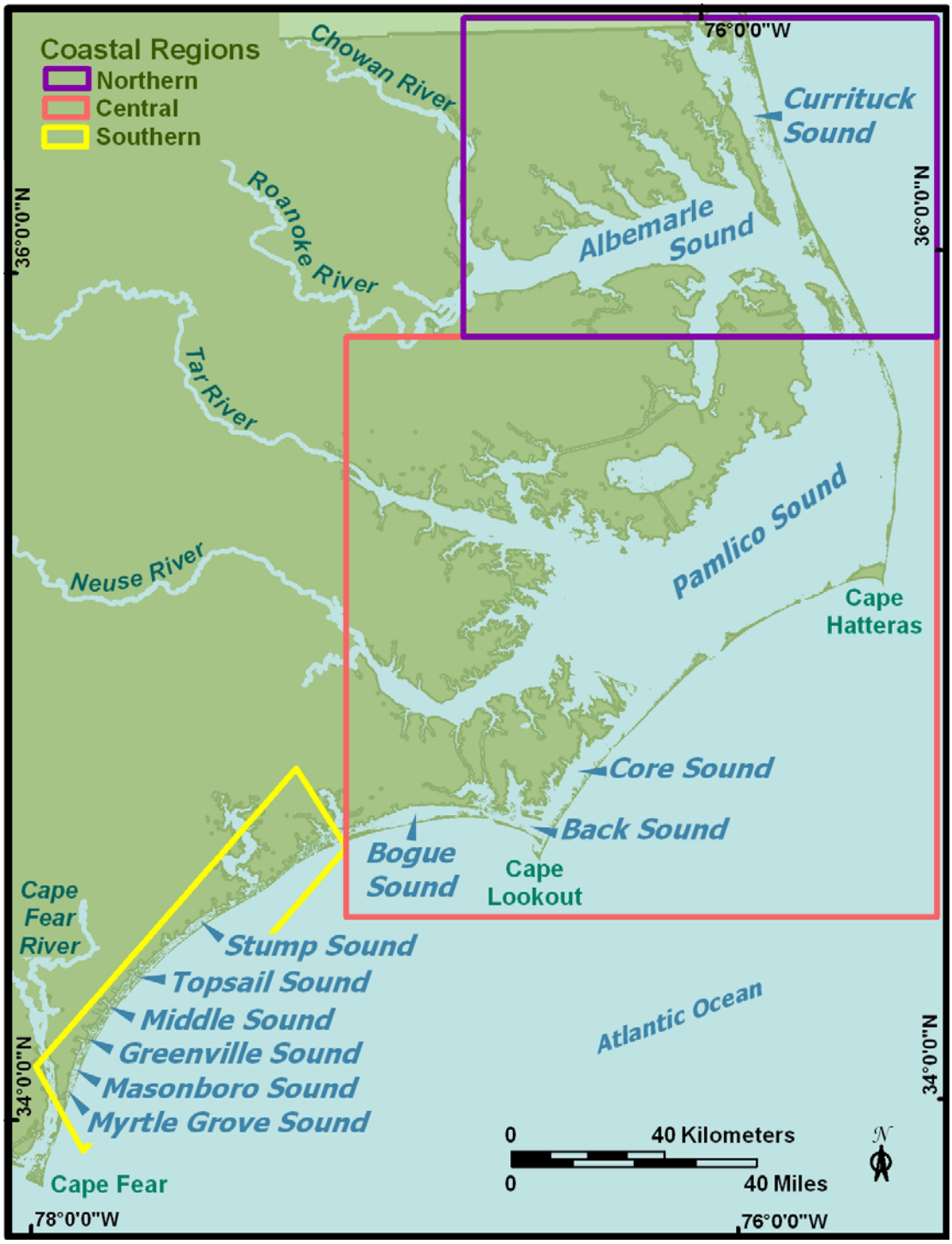

Figure 3: North Carolina coastal regions and back barrier sounds

The Northern coastal plain drains the Pasquotank, Chowan and Roanoke River Basins and is characterized by Quaternary age sediment deposits that occurred during the numerous sea level fluctuations in the past 1.6 million years (Pilkey et al. 1998). The sediments consist of unconsolidated mud, muddy sand, sand and peat sediments that thicken northward to fill the subsiding Albemarle Embayment. The consequence is a gently sloping topography with an average slope of only 0.2 feet per mile (Pilkey et al. 1998). Rising sea level combined with the gentle slope of the region has produced long barrier islands with drowned lowlands that lie behind the islands (Pilkey et al. 1998). In the north the long barrier islands project seaward and isolate the Albemarle Sound from the ocean. There are currently no inlets along the Northern coastline; the nearest inlets to Albemarle Sound are Lynnhaven Bay, Virginia (60 miles north of Kitty Hawk) and Oregon Inlet in Dare County, North Carolina (25 miles south of Kitty Hawk). Many ocean inlets existed throughout the history of the northern Outer Banks, however, by 1828, New Currituck Inlet, the last of the inlets, closed. This caused a transformation in Currituck and Albemarle Sounds from a high salinity estuarine environment to a low salinity (rarely exceeding 10 ppt salinity) estuarine environment that is affected by wind-dominated tides owing to the considerable distance from salt water. Albemarle Sound is connected to Pamlico Sound (in the Central region) and together they comprise the second largest estuarine complex in the continental U.S.

This region is rural but has recently experienced rapid population growth and development which is concentrated on the barrier islands. The mainland portion of the Northern coastal plain has also experienced a regional population increase but, for the most part, remains rural. The inland area of this region has been extensively cleared for agriculture and silviculture. Very few upland forests remain; however, there are swamp forests and extensive marshes that are associated with the major rivers and the sounds. Representative natural communities on the barrier islands include maritime shrub, maritime evergreen forest, estuarine fringe loblolly pine forest, and tidal freshwater marsh (North Carolina Natural Heritage Program (NCNHP) 1990).

The Central and Southern coastlines are underlain primarily by rocks dating from the Upper Cretaceous (about 90 million years ago) through Pliocene (about 1.6 million years ago) periods (Pilkey et al. 1998). The Central region drains the Tar, Neuse and White Oak River Basins into Pamlico Sound which is part of the Albemarle-Pamlico estuarine system. The Albemarle-Pamlico estuarine system is bounded to the east by long barriers islands with flooded lowlands behind the islands and covers more than 3,594 square miles (9,308 km^2) (Paerl et al. 2001). This region is characterized by shallow slopes and numerous inlets allowing the mixing of freshwater from the rivers and saltwater from the oceans.

The Central region is also a mostly rural region with a low-medium population density and numerous small towns. The agriculture and fishing industries are a major component of the local economy, though coastal communities are a destination for tourism and retirement, with new housing built primarily along the ocean, rivers and sounds. The region's topography is largely flat and poorly-drained. The coastal sites contain the following community types: maritime shrub forests, maritime evergreen forests, maritime dry grasslands, salt flats, dune grass communities and salt marshes. Just inland from these are the coastal edge sites, which contain coastal fringe evergreen forests, coastal fringe sandhills and maritime wet grasslands. Finally, away from the

tidal zone there are several types of inland communities, including pocosins, longleaf pine forests, nonriverine wetlands, and floodplain forests (NCNHP 1999).

The Southern coastal plain is associated with a large geologic structure called the Carolina Platform which has risen slightly during the geologic past causing the rocks to dip toward the north and east (Pilkey et al. 1998). Due to the unique uplifting of the Carolina Platform the Southern coastal plain is characterized by an average slope of 3 feet per mile (Pilkey et al. 1998). Rising sea level in this part of the State has led to the production of short, stubby barrier islands and narrow back-barrier estuaries (Pilkey et al. 1998). The Southern coastal plain drains the Cape Fear and Lumber River Basins and contains numerous inlets through the barrier islands allowing the rivers to fully mix with the ocean. As such the estuaries in the south are generally much smaller than those in the north and highly brackish (18-30 ppt).

The Southern region is the most highly developed along the North Carolina coastline and continues to experience substantial population growth. From 2000 to 2006, the coastal counties in this region saw a 22% increase in population (U.S. Census Bureau 2008). Despite development pressures, natural areas can still be found throughout the region. The mainland portion of the Southern region is characterized by nearly flat topography, with occasional bluffs along the rivers. There are extensive elevated peatland areas that support pocosin communities. Relict dune ridge-and-swale systems formed by an ancient ocean shoreline are present and support longleaf pine communities on the ridges and pocosin or swamp communities in the swales. In the southeastern part of the region, limesink ponds were formed by the localized underground collapse of limestone deposits, creating surface depressions. These elliptical depressions encircled by sand ridges support pocosin communities in the interior and longleaf pine communities along the bay rims. Along the Atlantic coast are barrier islands, which support significant tidal wetland and maritime forest communities (NCNHP 1995).

North Carolina's coastal plain is also divided into two different biogeographic regions (the Virginian and the Carolinian – Figure 2). Biogeographic regions are characterized chiefly by the dominant forms of plant life and the prevailing climate. The patterns of species distribution at the regional level can usually be explained through a combination of historical factors such as speciation, extinction, continental drift, and glaciation (and associated variations in sea level, river routes, and so on), in combination with the area and isolation of landmasses (geographic constraints) and available energy supplies. Each biogeographic region contains several types of estuarine ecosystems.

2. Climate and Weather

North Carolina, in the warm temperate zone, has a generally mild climate, with abundant and well distributed rainfall. Summer precipitation is typically highest, with July being the wettest month. Autumn is the driest season, with November the driest month. Precipitation during winter and spring occurs mostly in connection with migratory low pressure storms, which appear with greater regularity and in a more even distribution than summer showers. Snow and sleet are rare on the coastal plain (State Climate Office of North Carolina 2008).

Air temperature in North Carolina is extremely variable and depends on many factors such as altitude and the influence of oceanic currents. In all seasons, the average air temperature varies more than 20 °F (~11 °C) from the eastern most coastal areas compared to the highest mountain peaks. Winter air temperatures in the eastern portions of the coastal plain are modified by the Atlantic Ocean, which raises the average winter temperature and decreases the average day-to-night range compared to more inland areas. Average air temperature in summer (June-August) is 79 °F whereas the average winter air temperature (December-February) is 48 °F (State Climate Office of North Carolina 2008).

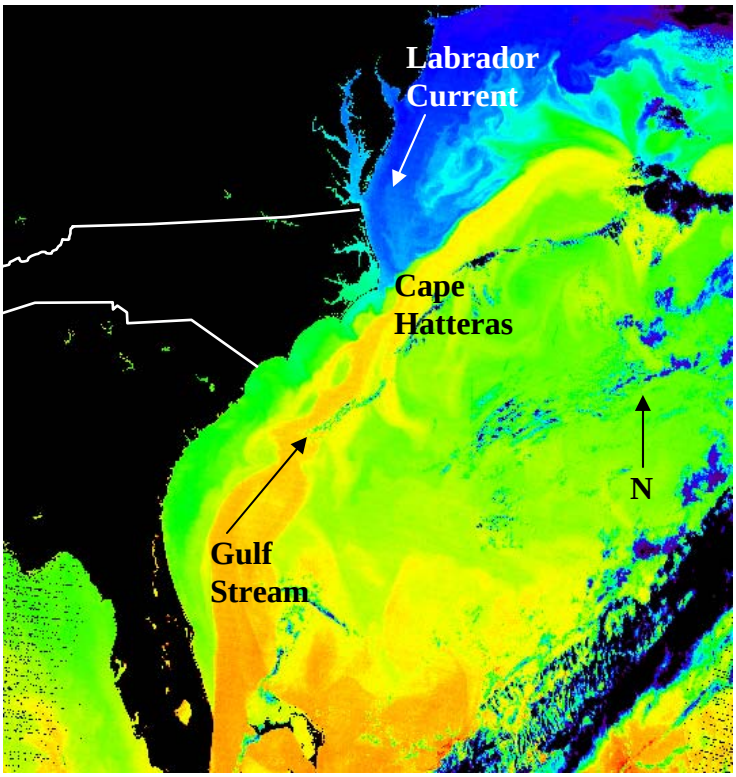

Figure 4: Ocean currents off of the coast of North Carolina. The warm waters of the Gulf Stream show up in yellow and move northward, the cold waters of the Labrador Current show up in blue and move southward

The immediate coastal regions of North Carolina are influenced greatly by the prevailing ocean currents. Two ocean currents, the Gulf Stream and the Labrador Current, converge off of Cape Hatteras (Figure 4). The Gulf Stream provides a warming effect to the southern coastal areas, and the Labrador Current provides a cooling effect for the northern coastal section. In the immediate coastal areas this can cause several degrees of difference between the northern (cooler) and southern (warmer) coastal areas. The convergence of these currents provides a rich biological region off the North Carolina coast where species from both the Carolinian (warmer) and Virginian (cooler) biogeographic provinces coexist. The mixing of the warm and cold waters also helps fuel oceanic storms off the coast of North Carolina. North Carolina is subject to two types of oceanic storms, tropical storm/hurricanes and Nor'easters. Both types of storms can produce large amounts of precipitation and gale force winds. Tropical storms and hurricanes are warm-cored systems with a closed circulation containing a defined eye wall structure. These storms are a yearly threat from June through November, and feed off the warm waters of the Gulf Stream. Nor'easters typically form during the winter months when a cold-cored low pressure system, associated with a front, moves up the coast and intensifies due to gradients in atmospheric conditions along the Labrador/Gulf Stream interface. Both storm types can influence areas well inland from the coast.

3. Estuaries

Estuaries are partially enclosed bodies of water, such as bays, sounds, lagoons and sloughs, where freshwater from rivers mixes with salt water from the oceans. North Carolina's 4,531 square miles (11,735 km^2) of estuarine and marine waters comprise the largest estuarine system of any state along the Atlantic coast (Paerl et al. 2001). The Albemarle-Pamlico estuarine system located in the Northern and Central regions is the second largest estuarine complex in the United States' lower 48 states and covers approximately 3,594 square miles (9,308 km^2). This estuarine system is composed of two very large sounds (Albemarle and Pamlico) and several small ones in the north (Currituck, Roanoke and Croatan) and south (Core, Back, and Bogue). The tidal range in these sounds is from 0.5 to 3.5 ft (~0.2 – 1 m) depending on distance from an ocean inlet. Salinity in the sounds also varies based on distance from an ocean inlet. Typical values range between 2-25 ppt (2-7 ppt in Albemarle Sound and 15-25 ppt in Pamlico Sound). The sounds in the southern region of North Carolina (Stump, Topsail, Middle, Greenville, Masonboro, and Myrtle Grove) are smaller than those to the north as the barrier islands tend to be much closer to the mainland than those northward. Consequently, their tidal range is closer to the coastal ocean values which in this region range from three to six ft (~0.9 – 1.8 m). Salinity in these sounds is also much closer to coastal ocean values ranging from 25-35 ppt. These differences in North Carolina's back barrier sounds make the estuarine environments in the northern, central and southern parts of the state very different.

The North Carolina coast includes almost 8,900 miles of estuarine shoreline, with a wide range of habitats. Estuaries and the lands surrounding them are places of transition from land to sea, and from fresh to saltwater. Estuarine environments are influenced by the tides yet are protected from the full force of ocean waves by barrier islands, reefs, or sand formations on the seaward boundary. Estuaries are among the most productive environments on earth and contain many different habitat types.

The state's central location on the East coast, vast estuarine system and extensive shoreline all play an important role in the health of fishery populations along the Atlantic coast. North Carolina is geographically situated at the convergence of the warm Gulf Stream flowing north and the cool Labrador Current flowing south. These two currents bring a wide variety of fish species into North Carolina's coastal waters. North Carolina's coastal waters support an abundant and vast assortment of marine life. Shrimp, flounder, trout, oysters, clams and hundreds of other species of fish and shellfish depend on the estuaries for all or some part of their lives. Many fish that live their lives in the ocean come to estuaries to lay eggs or give birth to young. The combination of shallow water and abundant vegetated habitat (marshes and submerged aquatic vegetation) makes excellent nursery habitat for fish, providing both food and refuge. Ninety-five percent of all commercial fish species caught in North Carolina utilize the estuary at some point during their life cycle. North Carolina, with its billion-dollar commercial and recreational fishing industries, ranks among the nation's highest seafood-producing states (State Library of North Carolina 2008).

Besides serving as important habitat for wildlife, the marshes that fringe estuaries also perform other valuable services. Stormwater runoff from the uplands carries sediments, nutrients, and other pollutants. As the runoff reaches the estuary it is filtered by the adjacent marsh. The

filtration process creates cleaner and clearer water thereby maintaining high water quality for both marine life and human enjoyment. Wetlands also act as a natural buffer during storms by absorbing flood waters and dissipating storm surges. Estuaries also provide many recreational opportunities, such as swimming, boating, fishing and bird watching.

B. Protection of Estuaries and Coasts: The Coastal Zone Management Act

To protect North Carolina's and the Nation's valuable estuarine resources, Congress passed the Coastal Zone Management Act (CZMA) and its subsequent reauthorizations to officially recognize that resources of the coastal zone are of national significance and that these resources are rapidly disappearing. The CZMA also recognizes the interrelationships between uplands and tidelands: the "coastal zone" was defined in the Act as including all uplands "to the extent necessary to control shoreland." A portion of the 1996 reauthorization of the CZMA states:

> *The increasing and competing demands upon the lands and water of our coastal zone...have resulted in the loss of living marine resources, wildlife, nutrient-rich areas, permanent and adverse changes to ecological systems, decreasing open space for public use, and shoreline erosion.*
>
> *The habitat areas of the coastal zone, the fish, shellfish, other living marine resources, and wildlife therein, are ecologically fragile and consequently extremely vulnerable to destruction by man's alteration.*

In recognition of these growing problems, the CZMA established a national goal:

> *...to preserve, protect, develop and, where possible, to restore and enhance the resources of the Nation's coastal zone for this and succeeding generations.*

The CZMA also recognized that coastal waters are significantly affected by land uses:

> *Land uses in the coastal zone, and the uses of adjacent lands which drain into the coastal zone, may significantly affect the quality of coastal waters and habitats, and efforts to control water pollution from land use activities must be improved.*

The CZMA authorizes two national programs: 1) the National Coastal Zone Management Program; and 2) the National Estuarine Research Reserve System.

1. National Coastal Zone Management Program

The National Coastal Zone Management Program (CZMP) is dedicated to comprehensive, sustainable management of the nation's coasts, seeking to manage and protect coastal resources while balancing often competing land and water uses. Coastal states must develop a coastal management program that will accomplish the following:

- Define the coastal zone boundary and permissible land and water uses;
- Outline methods by which the state will exert control over the uses;
- Define the organizational structure of the program and responsibilities of agencies involved; and
- Establish a planning process to address public access, energy facilities, and assessing shoreline erosion rates.

A National Oceanic Atmospheric Administration (NOAA) approved coastal management plan also gives states some control over federal actions affecting the state's coastal zone. Reauthorizations of the CZMA have incorporated the Coastal Nonpoint Pollution Control Program, for states to manage the effects of nonpoint source pollution, and Management Program Enhancements, for states to make improvements to their coastal programs. States utilize a variety of tools to implement the coastal management programs including planning, permitting, and enforcement. The CZMP provides federal technical assistance, funding, and national coordination to support states' coastal zone management planning and plan implementation.

As a consequence, the North Carolina General Assembly passed the Coastal Area Management Act (CAMA) in 1974, creating one of the first state coastal programs in the nation. The N.C. Division of Coastal Management carries out the CAMA, in addition to the Dredge and Fill Law and the Federal CZMA of 1972, in the 20 coastal North Carolina counties using rules and policies of the N.C. Coastal Resources Commission.

2. National Estuarine Research Reserve System

The National Estuarine Research Reserve System (NERRS) was created by the CZMA of 1972, as amended, 16 United States Code (USC) Section 1461, to augment the CZMP. The Reserve System is a network of protected areas established to promote informed management of the Nation's estuaries and coastal habitats. The Reserve System currently consists of 27 Reserves in 22 states and territories, protecting over one million acres of estuarine lands and waters (Figure 5).

a. Mission

As stated in the NERRS regulations (Appendix A), 15 Code of Federal Regulations (CFR) Part 921.1(a), the NERRS mission is:

> *…the establishment and management, through Federal-state cooperation, of a national system of Estuarine Research Reserves representative of the various regions and estuarine types in the United States. Estuarine Research Reserves are established to provide opportunities for long-term research, education, and interpretation.*

b. Goals

Federal regulations, 15 CFR Part 921.1(b), provide five specific goals for the Reserve System:

1. Ensure a stable environment for research through long-term protection of National Estuarine Research Reserve resources.
2. Address coastal management issues identified as significant through coordinated estuarine research within the System.
3. Enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation.
4. Promote Federal, state, public and private use of one or more Reserves within the System when such entities conduct estuarine research.

5. Conduct and coordinate estuarine research within the System, gathering and making available information necessary for improved understanding and management of estuarine areas.

c. Administrative Framework of NERRS

The Estuarine Reserves Division (ERD) of the Office of Ocean and Coastal Resource Management (OCRM) administers the Reserve System. ERD establishes standards for designating and operating Reserves, provides support for Reserve operations and system-wide programming, undertakes projects that benefit the Reserve System, and integrates information from individual Reserves to support decision-making at the national level. As required by Federal regulation, 15 CFR Part 921.40, OCRM periodically evaluates Reserves for compliance with federal requirements and with the individual Reserve's Federally-approved management plan.

ERD currently provides support for three system-wide programs: the System-Wide Monitoring Program (SWMP), the Graduate Research Fellowship Program (GRF), and the Coastal Training Program (CTP). They also provide support for Reserve initiatives on restoration science, invasive species, K-12 education, and Reserve specific research, monitoring, education and resource stewardship initiatives and programs.

d. NERRS Strategic Goals 2005-2010

The Reserve System began a strategic planning process in 1994 in an effort to help NOAA achieve its environmental stewardship mission to "sustain healthy coasts." In conjunction with the strategic planning process, ERD and Reserve staff has conducted a multi-year action planning process on an annual basis since 1996. The resulting three-year action plan provides an overall vision and direction for the Reserve System. As part of this process, the Reserve System developed a vision: Healthy estuaries and watersheds where coastal communities and ecosystems thrive; and mission: To practice and promote coastal and estuarine stewardship through innovative research and education, using a system of protected areas. The following goals are outlined in the 2005-2010 Strategic Plan (Appendix B):

1. Strengthen the protection and management of representative estuarine ecosystems to advance estuarine conservation, research and education.
2. Increase the use of Reserve science and sites to address priority coastal management issues.
3. Enhance people's ability and willingness to make informed decisions and take responsible actions that affect coastal communities and ecosystems.

High priority science and training needs for coastal managers were selected based on their appropriateness to the NERRS mission to focus the System's efforts locally and nationally. These topics will be addressed by implementing the strategic goals.

Figure 5: National Estuarine Research Reserve System map and biogeographic region

Acadian – Southern Gulf of Maine
Wells Reserve, Maine (1984)
Great Bay Reserve, New Hampshire (1989)
Virginian – Southern New England
Waquoit Bay Reserve, Massachusetts (1988)
Narragansett Bay Reserve, Rhode Island (1980)
Hudson River Reserve, New York (1982)
Virginian – Middle Atlantic
Jacques Cousteau Reserve, New Jersey (1998)
Delaware Reserve (1993)
Virginian – Chesapeake Bay
Chesapeake Bay Reserve, Maryland (1985,1990)
Chesapeake Bay Reserve, Virginia (1991)
Virginian & Carolinian – North Carolina
North Carolina Reserve (1985, 1991)
Carolinian – South Atlantic
North Inlet-Winyah Bay Reserve, South Carolina (1992)
ACE Basin Reserve, South Carolina (1992)
Sapelo Island, Georgia (1976)
Carolinian – East Florida
Guana Tolomato Matanzas Reserve, Florida (1999)
West Indian – Caribbean
Jobos Bay Reserve, Puerto Rico (1981)
West Indian – West Florida
Rookery Bay Reserve, Florida (1978)

Louisianan – Panhandle Coast
Apalachicola Reserve, Florida (1979)
Weeks Bay Reserve, Alabama (1986)
Louisianan – Mississippi Delta
Grand Bay Reserve, Mississippi (1999)
Louisianan – Western Gulf
Mission-Aransas Reserve, Texas (Proposed)
Californian – Southern California
Tijuana River Reserve, California (1982)
Californian – Central California
Elkhorn Slough Reserve, California (1979)
Californian – San Francisco Bay
San Francisco Bay, California (2003)
Columbian – Middle Pacific
South Slough Reserve, Oregon (1974)
Columbian – Puget Sound
Padilla Bay Reserve, Washington (1980)
Great Lakes – Lake Erie
Old Woman Creek, Ohio (1980)
Great Lakes – Lake Ontario
St. Lawrence River, New York (Proposed)
Fjord – Aleutian Islands
Kachemak Bay Reserve, Alaska (1999)

Reserve System Priority Coastal Management Issues:

1. Land Use and Population Growth
2. Habitat Loss and Alteration
3. Water Quality Degradation
4. Changes in Biological Communities

e. Designation and Operation of NERRS

Under Federal law (16 USC Section 1461), a State can nominate an estuarine ecosystem for Research Reserve status so long as the site meets the following conditions:

1. The area is representative of its biogeographic region, is suitable for long-term research and contributes to the biogeographical and typological balance of the System;
2. The law of the coastal State provides long-term protection for the proposed Reserve's resources to ensure a stable environment for research;
3. Designation of the site as a Reserve will serve to enhance public awareness and understanding of estuarine areas, and provide suitable opportunities for public education and interpretation; and
4. The coastal State has complied with the requirements of any regulations issued by the Secretary [of Commerce].

Reserve boundaries must include an adequate portion of the key land and water areas of the natural system to approximate an ecological unit and to ensure effective conservation (Appendix C).

If the proposed site is accepted into the Reserve System, it is eligible for NOAA financial assistance on a cost-share basis with the State. The State exercises administrative and management control, consistent with its obligations to NOAA, as outlined in a Memorandum of Understanding (MOU). A Reserve may apply to NOAA's ERD for funds to help support operations, research, monitoring, education/interpretation, stewardship, development projects, facility construction, and land acquisition.

NOAA has identified eleven distinct biogeographic regions and 29 sub-regions in the United States (U.S.), each of which contains several types of estuarine ecosystems (15 CFR Part 921). When complete, the Reserve System will contain examples of estuarine hydrologic and biological types characteristic of each biogeographic region. As of 2008, the Reserve System includes 27 Reserves (Figure 5). The Reserves are listed in Figure 5 by biogeographic region and sub-region with their designation date denoted in parentheses. Three components of the North Carolina National Estuarine Research Reserve (NCNERR) were designated in 1985 (Currituck Banks, Rachel Carson, and Zeke's Island) and Masonboro Island was designated six years later in 1991.

f. Reserve Management Plans

Every Reserve is required by Federal Regulation to have an ERD-approved management plan. The plan must describe the Reserve's goals, objectives and management issues, and must identify the Reserve's intended strategies or actions for research,

education/interpretation, public access, construction, acquisition, and resource management. Staff roles in each of these areas must also be addressed. Reserve management plans are important for a variety of reasons, including:

- Provide a framework to direct and evaluate Reserve programs;
- Gauge how successfully Reserve goals have been met and determine necessary changes in direction; and,
- Guide Section 312 programmatic evaluations of the Reserve.

To serve these purposes, management plans are currently required by NOAA to be updated every five years. This revised management plan for the North Carolina National Estuarine Research Reserve has been developed in accordance with NOAA regulations, including all provisions for public involvement (Appendix D). It is consistent with the Section 315 of the CZMA of 1972, as amended, and the provisions of the North Carolina Coastal Management Program.

C. North Carolina National Estuarine Research Reserve

As the regulatory and planning programs of CAMA were implemented by the Division of Coastal Management (DCM) in the late 1970s, it became apparent that an effective, comprehensive coastal management program must include a land acquisition program. To fill this gap, two land acquisition programs – the beach access and North Carolina Coastal Reserve programs – were incorporated into CAMA in the 1980s. The NCNERR was the precursor to the North Carolina Coastal Reserve; the NCNERR's success in protecting coastal and estuarine habitats for research and education inspired the State to protect additional coastal and estuarine habitats thus creating the North Carolina Coastal Reserve.

1. Establishment of the Reserve

North Carolina's diverse estuarine systems include more than 2.9 million acres and represent two biogeographic regions, the Virginian and the Carolinian, which converge just north of Cape Hatteras (Figure 2). The diverse range of habitats in North Carolina noted above make it an ideal location for a National Estuarine Research Reserve. In order to capture the full breadth of this diversity, a multi-component NERR was planned for the State. This approach allowed all the estuarine ecosystems present in the State to be represented and protected. In 1982 the State of North Carolina received its first federal award toward the establishment of the NCNERR. Four properties were selected to become components of NCNERR. These properties protect approximately 10,500 acres of land and water habitat from the northern, central and southern parts of North Carolina.

Three of the components were designated in 1985 (Currituck Banks, Rachel Carson, and Zeke's Island) and Masonboro Island was designated six years later in 1991. The four components are owned in fee simple by the State of North Carolina. The four components include:

1. The 965-acre Currituck Banks component located in Currituck County, just north of the village of Corolla at the end of N.C. 12;
2. The 2,315-acre Rachel Carson component located in Carteret County between the town of Beaufort, Harkers Island and the Cape Lookout National Seashore;

3. The 5,653-acre Masonboro Island component, an undeveloped barrier island, situated in New Hanover County between the towns of Wrightsville Beach and Carolina Beach; and
4. The 1,635-acre Zeke's Island component, encompassing tracts in both New Hanover and Brunswick counties, reached via U.S. 421 south of Kure Beach (Figure 6).

The NCNERR is a federal-state partnership between NOAA and the North Carolina Department of Environment and Natural Resources' DCM (Appendix E). Refer to the Administration Plan within this document for more information regarding the administrative framework of the NCNERR.

2. State Management Authority

North Carolina state law (General Statutes 113A-129.1-.3; Article 7, Coastal Area Management Act) complements and reinforces the federal NERRS regulations by declaring that management of the NCNERR, as part of the Coastal Reserve, is state policy (Appendix F). The 1989 statute also establishes the basic Reserve purpose:

> *Important public purposes will be served by the preservation of certain areas in an undeveloped state. Such areas would thereafter be available for research, education, and other consistent public uses. These areas would also continue to contribute perpetually to the natural productivity and biological, economic, and aesthetic values of North Carolina's coastal area.*

The Department of Environment and Natural Resources (DENR) promulgated rules in 1986 for the Reserve sites within the North Carolina Administrative Code (T15: 7O). These rules were established to further define the purpose, responsibilities, functions, components, and use requirements for the Reserve components (Appendix G). The Coastal Reserve includes the four NCNERR components (Currituck Banks, Rachel Carson, Masonboro Island, and Zeke's Island) plus six state sites: Kitty Hawk Woods (Dare County), Buxton Woods (Dare County), Buckridge (Tyrrell and Hyde Counties), Permuda Island (Onslow County), Bald Head Woods (Brunswick County), and Bird Island (Brunswick County) (Figure 6).

The NCNERR is also designated as a State Nature Preserve, which is a limited use area that serves to preserve and portray the natural features unique to the region (Appendix H). Some Reserve components are subject to county and municipal zoning regulations (see Appendix I for these applicable regulations).

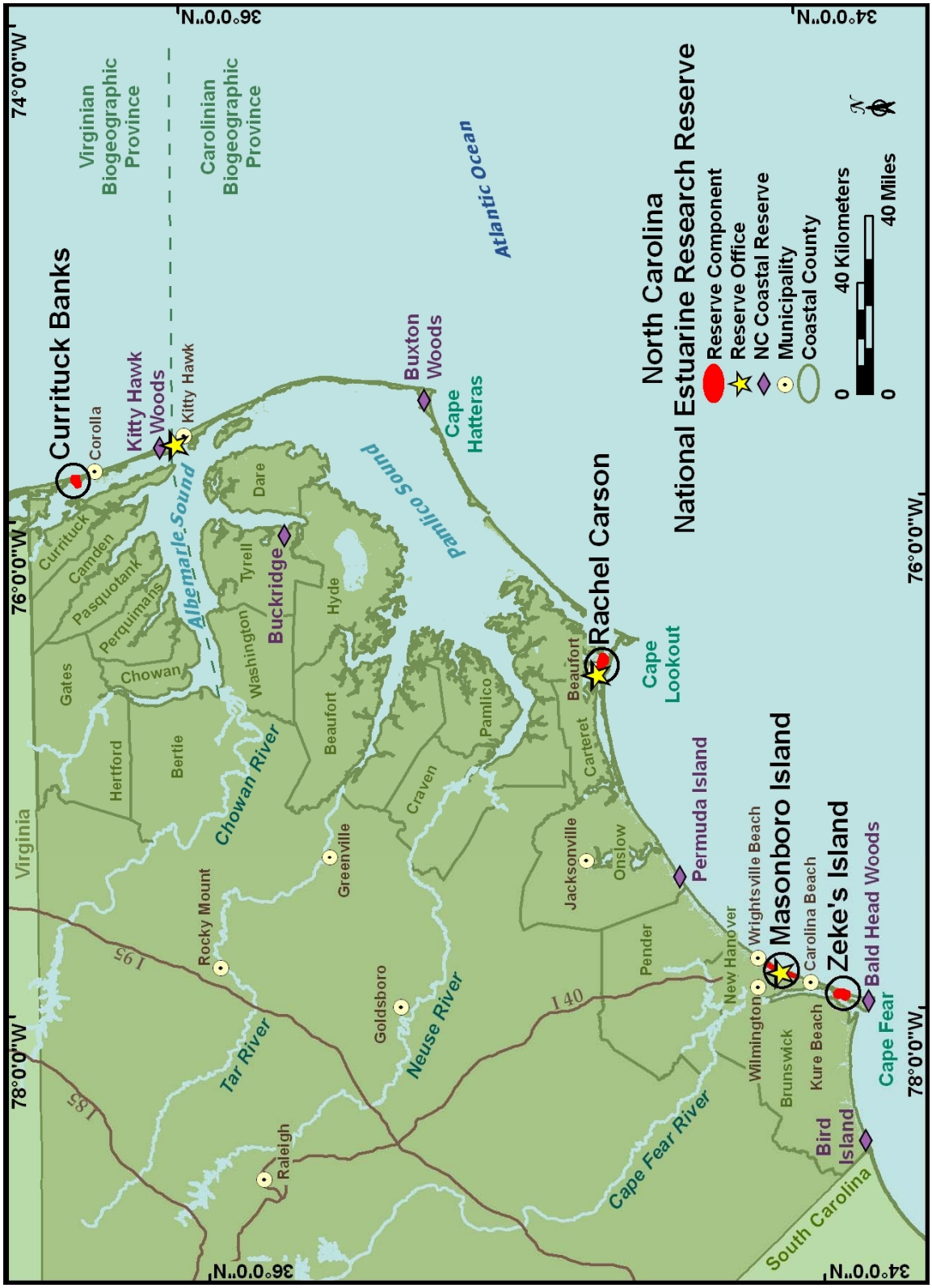

Figure 6: Map of the locations of NCNERR components on the North Carolina coast

3. NCNERR Focus for 2009-2014

The vision, mission, and goals below were developed by NCNERR staff through strategic planning and logic model tools with the assistance of the NOAA Coastal Services Center.

a. Vision

Healthy estuaries and coastal watersheds where ecological communities thrive and the human community benefits in North Carolina.

b. Mission

To promote informed management and stewardship of North Carolina's estuarine and coastal habitats through research, education, and example.

c. Goals

The goals and objectives integrate NCNERR programs, obscuring the lines between education, research, and stewardship. Table 1 details the Reserve-specific goals and objectives and demonstrates the interconnectedness of the NCNERR. The subsequent chapters of the management plan (administration, education, research, stewardship, and land acquisition) parse the objectives and activities into the program areas. For example, objective 1.2 involves both the education and stewardship sectors and thus, the objective is included in both the education and stewardship chapters with program-appropriate activity descriptions in each.

Table 1: NCNERR goals and objectives

Goal 1. Humans understand the natural systems, their connections to them, and the benefits derived from them.
Objective 1.1 - Education programs will deliver information on N.C. coastal resources to formal and informal educators, and K-12 and college students to foster environmental stewardship and informed decision-making.
Objective 1.2 - The greater community, including the general public, visitors, and pre-school children, will receive educational programming.
Objective 1.3 – Coastal Training Program (CTP) activities will deliver science-based knowledge and skills appropriate to the needs of target audiences and relevant to sustainable coastal management.
Goal 2. Applicable research informs coastal policy.
Objective 2.1 - NCNERR research products will be used by the coastal management community.
Objective 2.2 - The NCNERR will enhance implementation of the System-Wide Monitoring Program.

Table 1 continued: NCNERR goals and objectives

Goal 3. NCNERR habitats and land use of associated watersheds are characterized and connections understood.
Objective 3.1 - NCNERR habitat and watershed maps will inform management of the sites and improve understanding of watershed connections.
Objective 3.2 - Restored NCNERR habitats will provide improved water quality and ecological function.
Goal 4. Habitat is protected and the public has directed access to NCNERR sites.
Objective 4.1 - Effective Reserve site management will ensure a stable environment for research and education.
Objective 4.2 - Boundary expansion and acquisition will be completed to effectively protect Reserve core and buffer areas.
Objective 4.3 - Coastal systems and their value will be interpreted and access to the Reserve sites will be directed to representative habitats to reduce impacts on sensitive habitats.
Goal 5. NCNERR operations, infrastructure, and stature are improved.
Objective 5.1 - The NCNERR will strengthen its relationship with NOAA-Estuarine Reserves Division (ERD).
Objective 5.2 - The NCNERR will strengthen its relationship with DCM.
Objective 5.3 - The NCNERR will strengthen its relationship with University of North Carolina – Wilmington (UNCW) and Center for Coastal Fisheries and Habitat Research (CCFHR).
Objective 5.4 - The NCNERR will assess use of the sites by various education, research, and commercial entities.
Objective 5.5 - The NCNERR will ensure its operating infrastructure is adequate to fulfill the program mission.
Objective 5.6 - The NCNERR will ensure its staff has the skills necessary to perform their jobs and are able to do so safely.
Objective 5.7 - The community will recognize the NCNERR and understand how the Reserve serves the citizens and visitors of North Carolina.
Objective 5.8 - The NCNERR needs will be more fully met by volunteers and volunteers will be trained in coastal issues.

Goals 1-4 above directly support the 2005-2010 NERRS Strategic Plan goals as outlined in Appendix B. NCNERR goal 1 is a broadly defined educational goal which addresses NERRS Strategic Goals 2 and 3 by fostering environmental stewardship and informed decision-making. NCNERR goal 2 focuses on increasing the use of Reserve research to inform and address priority coastal management issues (NERRS Goal 2). NCNERR goals 3 and 4 strengthen the protection and management of North Carolina's estuarine ecosystems (NERRS Goal 1). NCNERR goal 5 supports the other goals through improved operations and infrastructure.

d. Guiding Principles

The guiding principles detail how the NCNERR conducts its business, providing a filter through which programs are developed, implemented, and evaluated. These principles apply to all programs and sites.

- Strong partnerships between the NCNERR, federal and state agencies, universities, other local partners, and the Carolina Estuarine Reserve Foundation are critical to the success of the NCNERR.
- The NCNERR integrates science, education, and stewardship on relevant topics to maximize the benefits to coastal management.
- The NCNERR engages local communities and citizens to improve stewardship of coastal areas.
- Reserve programs capitalize on the physical setting of the Reserve to inspire questions, learning, and conscious decision-making.
- The management and programs of the Reserve demonstrate good environmental practices.

e. NCNERR Programs

NCNERR is operationally divided into three distinct sectors: education, research, and stewardship. Each sector is devoted to fostering that aspect of the program, under the guidance of the Reserve manager and according to the management plan. The Education sector, through programs and activities, strives to increase understanding and awareness of estuarine systems and improve decision-making among key audiences to promote stewardship of North Carolina's coastal resources. The Research sector addresses scientific and technical aspects of coastal management problems through a comprehensive, interdisciplinary, and coordinated research program including site-directed research, monitoring, and the Graduate Research Fellowship Program. The Stewardship sector is involved in a wide range of activities including land acquisition, ecological restoration, resource inventories, watershed management projects, endangered species protection, visitor use management, regional planning, policy development and more. Each sector supports the overall mission of the Reserve to promote informed management and stewardship of North Carolina's estuarine and coastal habitats.

4. Coastal Management Issues in North Carolina

There are several overarching issues faced by the entire North Carolina coast that threaten all components of the NCNERR. These include both anthropogenic influences as well as natural processes. Issues affecting all NCNERR components include coastal population increase, altered land use, storm water runoff and eutrophication, invasive species, tropical and coastal storm impacts, and sea level rise. Objectives that address these overarching issues are summarized in Table 2 and are discussed in more detail in the education, research and stewardship plans. In addition to these overarching issues, individual Reserves have specific local issues that are threats as well. These individual Reserve-specific issues are documented within each of the

subsequent Reserve component descriptions and are addressed in detail in relevant objectives in the education, research and stewardship plans. All of these issues are interconnected. Changes in one induce changes in another and vice versa. The following paragraphs provide a brief summary of how these threats impact the NCNERR properties.

Coastal Population Increase

The NCNERR properties are especially vulnerable to impacts associated with increased coastal population. The counties that contain the NCNERR properties have witnessed dramatic population increases over the 2000 to 2006 time period. Currituck County (includes Currituck Banks) has seen a 31% increase, Carteret County (includes Rachel Carson) has seen a 7% increase, New Hanover County (includes Masonboro Island and a portion of Zeke's Island) has seen a 14% increase and, Brunswick County (includes the other portion of Zeke's Island) has seen a 30% increase (U.S. Census Bureau 2008).

As the human population increases, so do the impacts upon the environment including increased storm water runoff and eutrophication (see below), increased sewage, trash, and emissions. The increased population also leads to increases in the number of people using the Reserve properties. While most visitor use of the Reserves is benign and causes no harm, occasional misuse of the properties does occur. These are usually associated with visitors not knowing the allowed uses for the properties and include things like, illegal hunting and camping, dogs off leash, and accumulation of trash.

Land Use and Eutrophication

Altered land use and cover is a critical issue because how the land is used and the type of cover on it has large impacts on its ability to sequester nutrients and pollution rather than convey them to surface waters. Natural land covers such as forest and marsh have large buffering capacities. They tend to trap nutrients and sediment prior to their entering surface waters. Developed land tends to have very little capacity to absorb nutrients and pollution (Mallin et al. 2000a). This is because developed land has increased impervious surfaces such as roofs, roads, and parking lots. These surfaces do not allow water to infiltrate the ground and high percentages of impervious surfaces have been correlated with degraded water and sediment quality (Mallin et al. 2000a; Holland et al. 2004). Consequently runoff from these surfaces, especially during storm events, picks up whatever contaminants and nutrients are on them and rapidly moves these materials to surface waters (Mallin et al. 2000a; Mallin et al. 2001). This stormwater runoff has the ability to severely impact receiving waters by increasing eutrophication.

Eutrophication is a process through which natural waters receive too many nutrients. Nutrients, especially nitrogen and phosphorus, stimulate phytoplankton production. This increased production can lead to a multitude of water quality problems including hypoxia, decreased light penetration, altered community composition, loss of submerged aquatic vegetation (SAV), and decreased fish and shellfish populations. Recovery from eutrophication can take long periods of time even if the causes of the eutrophication are immediately halted (Nixon 1995; Paerl et al. 1998; Mallin et al. 2000b; Niemi et al. 2004). Because of the population increases noted above

and the associated land use changes, the NCNERR properties are vulnerable to water quality declines as a result of eutrophication.

Invasive Species

Invasive species is one of the largest and most pervasive problems facing not only NCNERR but also the nation. An invasive species is one that begins to live and reproduce in an area where it is not naturally found. This is problematic because when this happens there usually are not any natural predators capable of keeping the invader in check, and the new species tends to utilize resources at the expense of an existing native one. Invasive species are usually very opportunistic and hard to get rid of once established. The Reserve also has several animal species that were once domesticated but are now wild or feral. Feral animals are also problematic in that they are often not native to Reserve habitats. Invasive and feral species known to occur on the Reserve properties include Beach Vitex (*Vitex rotundifolia*), French Tamarisk (*Tamarix gallica*), Red Fox (*Vulpes vulpes*), Nutria (*Myocastor coypus*), Common Reed (*Phragmites australis*), Feral Pig (*Sus scrofa*), and Feral Horse (*Equus caballus*).

Storms

North Carolina's geography makes it prone to strikes by tropical and coastal storm systems. The North Carolina coast has been impacted by 14 named storms since 2000. These storms can bring tremendous amounts of wind and rain to the coastal region. They also are capable of causing significant shoreline erosion and can even cause new inlets to form. All of these potential impacts are important for the properties of NCNERR which are all coastal barriers located at the interface between the ocean and land.

Sea Level Rise

Sea level rise is occurring along the North Carolina coast. Estimates for the amount of rise range from 0.3 to 3.0 mm/year, with most values between 1-2 mm/year (Gormitz 1995). There are many potential problems associated with an increase in sea level. The most important in terms of the Reserve properties is loss of marsh or habitat. If the sea level rise is faster than the ability of the marsh to accrete sediment and build itself up, then the marshes will be flooded (Moorhead & Brinson 1995). This would cause not only a decrease in the size of all the Reserve properties, but also would represent a loss of vital nursery habitat and other values of marshes. Increased sea level will also enhance shoreline erosion within the Reserve properties potentially leading to loss of upland areas as well.

The issues described above are ubiquitous along the coast of North Carolina and the implementation of the objectives outlined in this management plan, though focused on NCNERR sites, is transferable to other resource managers and partners in North Carolina. A matrix of where the Reserve addresses these overarching issues within the Management Plan is found below (Table 2).

Table 2: NCNERR goals and objectives that address the priority coastal management issues in N.C.

	COASTAL MANAGEMENT ISSUES IN N.C.				
GOALS & OBJECTIVES	**Population Increase**	**Land Use & Eutrophication**	**Invasive Species**	**Storms**	**Sea Level Rise**
Goal 1 – Humans understand…					
Obj. 1.1 - K-12 educ. programs	X	X	X	X	X
Obj. 1.2 – General public	X	X	X	X	X
Obj. 1.3 – CTP	X	X	X	X	X
Goal 2 – Research informs…					
Obj. 2.1 – Coastal management	X	X	X	X	X
Obj. 2.2 – SWMP		X			
Goal 3 – Habitats and land use…					
Obj. 3.1 – Habitat maps		X	X		
Obj. 3.2 – Restored habitats	X	X	X	X	X
Goal 4 – Habitat is protected…					
Obj. 4.1 – Site management	X	X	X	X	X
Obj. 4.2 – Boundary expansion					
Obj. 4.3 – Directed access	X		X		
Goal 5 – Operations improved…					
Obj. 5.1 – NOAA-ERD					
Obj. 5.2 – DCM					
Obj. 5.3 – UNCW & CCFHR					
Obj. 5.4 – Site usage	X				
Obj. 5.5 – Infrastructure					
Obj. 5.6 - Staff development					X
Obj. 5.7 – Recognize NCNERR					
Obj. 5.8 – Volunteer program					

5. NCNERR Component Descriptions

The North Carolina NERR was established as a multi-component Reserve to include sites in both the Virginian and Carolinian biogeographic region as well as the three regions of the coastal plain. As a consequence the Reserve is made up of four geographically disparate components consisting of unique representative estuarine habitats. During the formative years of NCNERR, there was not enough staff to conduct research, education and stewardship activities at all components. This problem was alleviated by concentrating sector activities at certain Reserve components. The research staff and activities were concentrated in Wilmington, N.C. at the Masonboro and Zeke's Islands components. Education programs, including the Coastal Training Program (CTP) which focuses on adult decision-makers, and staff were concentrated in the Beaufort, N.C. area at the Rachel Carson component. The stewardship staff and activities were located in Kitty Hawk, N.C. and primarily worked at the Currituck Banks component.

A recent internal evaluation of programs, facilities, current staffing levels, and projected staffing needs revealed there are needs and opportunities for core programs at all offices. Through staff reorganization, creation of new positions and new partnerships the NCNERR is working toward a new philosophy where research, education and stewardship activities are conducted at all locations. Program priorities were established for each component based on existing

infrastructure, staffing, site-specific needs, and current program resources (Table 3). The matrix below will be used as an internal planning tool to focus our limited resources.

Table 3: Programmatic capabilities based on existing infrastructure, staffing and site-specific needs.

NCNERR Component	Stewardship	Community Education and Outreach	K-12 Education	Coastal Training Program	Research
Currituck Banks NERR	High	Medium	Low	Medium	Medium
Rachel Carson NERR	Medium	High	High	High	Medium
Masonboro Island NERR	High	High	Low	Medium	High
Zeke's Island NERR	Medium	Low	Medium	Low	High

A description of each component including location, biogeographic province, landform type, habitat type, representative native and non-native species, site-specific issues and program priorities, is given below. All components are described in detail in the Reserve's Site Profile (www.nccoastalreserve.net). Specific information on core and buffer area requirements and maps of these areas for each component can be found in Appendix C.

a. Currituck Banks

Location and Description

The Currituck Banks component of the NCNERR is the northern most component and is the only component located in the Virginian biogeographic province (Figure 6). Currituck Banks encompasses 965 acres (3.9 km^2) in the northeastern corner of North Carolina in Currituck County, just north of the unincorporated village of Corolla, ten miles (16 km) south of the Virginia border. The nearest population center is Elizabeth City, N.C., approximately 20 miles (~32 km) to the west across Currituck Sound. The Nature Conservancy and U.S. Fish and Wildlife Service properties bound Currituck Banks to the north (Appendix J), the Atlantic Ocean to the east, the Currituck Sound to the west, and private subdivisions of Corolla to the south (Figure 7).

Currituck Banks is located in the Pasquotank River Basin. Currituck Banks is accessible by foot traffic and boat. The nearest boat ramp is located next to the Currituck Lighthouse in Corolla. The ocean beach portion of the Reserve is accessible by four-wheel drive along the beach corridor after N.C. 12 terminates at the beach access ramp. Two walking trails exist at the southern portion of the site just off state route N.C. 12 where public parking and handicap access is available.

The Currituck Banks component is included in the NCNERR because it is an excellent example of an undisturbed cross-section of a barrier island in a low-salinity estuarine system. The delimited portion of Currituck Sound and the associated marshes constitute the core area proper (721 acres) of the component. The sound waters contain extensive mud and sand flats covered in some areas by submerged aquatic vegetation. Ocean beaches, upland dunes, shrub thickets, maritime forests, and interdune ponds comprise the buffer communities (244 acres) of the component. The mature maritime deciduous forest within the component's boundaries is one of the rarest habitat types on the U.S. east coast (Schafale & Weakley 1990). The interior uplands are characterized by dense woody vegetation intermingled with numerous seasonal wetlands. This mosaic of habitats effectively restricts public use to the ocean beach area. The 1/3-mile boardwalk, walking trail and parking site are in the buffer area of this component.

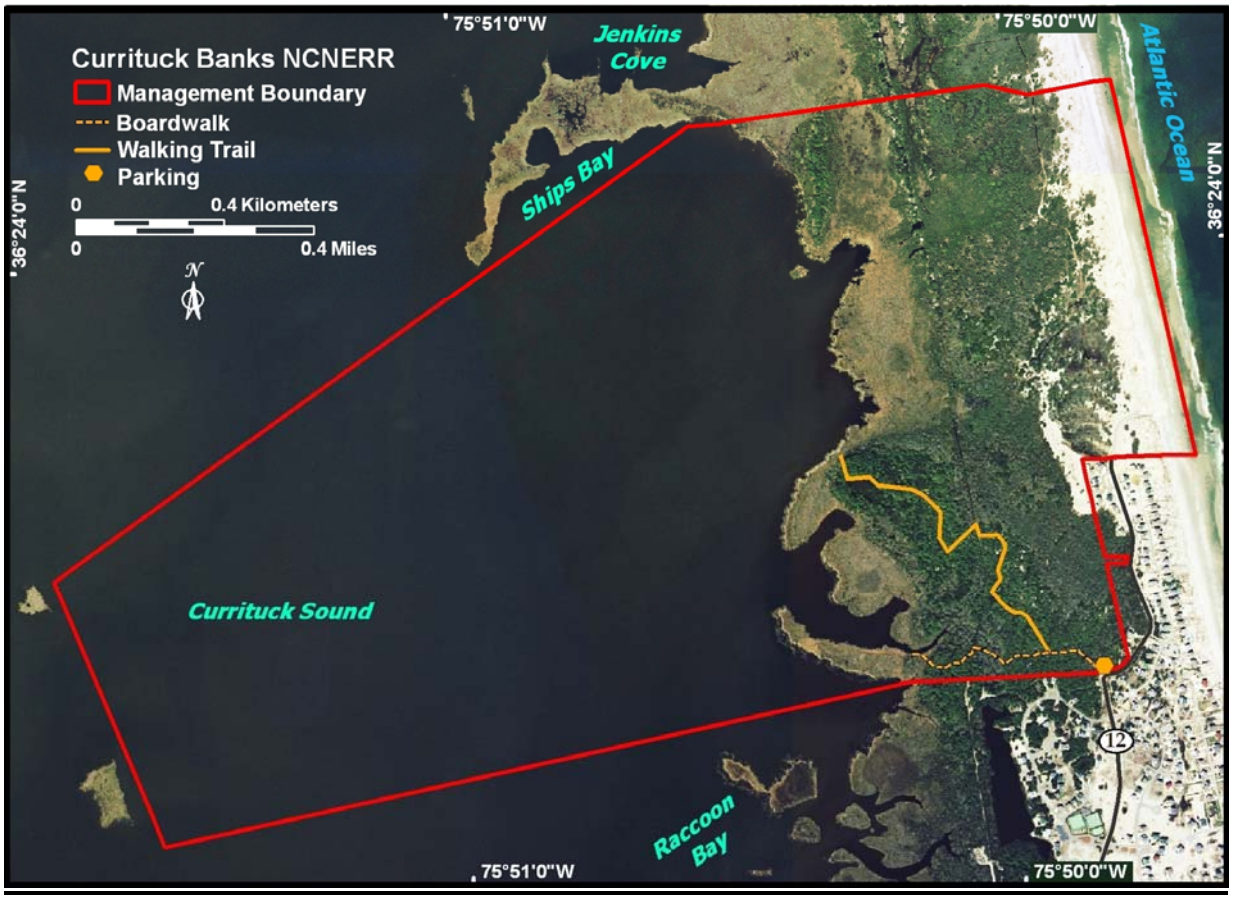

Figure 7: Currituck Banks site map

Throughout recent geologic time, the barrier landform that includes Currituck Banks has been very dynamic. It has migrated inland in response to sea level changes, and several inlets have opened and closed. Currently the landform is a solid barrier spit that extends about 70 miles (113 km) from Virginia Beach, V.A. to Oregon Inlet, N.C. This limits sound to ocean exchange and because of the distance to the Oregon Inlet, Currituck Sound is a wind driven, predominately fresh body of water. Extensive areas of brackish marshes border Currituck

Sound, and vast meadows of submerged aquatic vegetation exist in the shallower regions. These features provide research opportunities that cannot be found anywhere else in North Carolina.

The weather of Currituck Banks is typical of a maritime climate on the Outer Banks where the ocean has a strong moderating effect on air temperature compared to the mainland areas. Climatologically, Currituck Banks is classified as subtropical with humid, warm summers and mild winters. The mixing of the warm Gulf Stream Current and cooler Labrador Current off Currituck Banks creates a climate where northern species reach the southern limit of their ranges and southern species reach the northern limit of their ranges. As a result, a diversity of species from both regions is found here. Birds found in the area that are of special concern include the black skimmer, least tern, common tern and tri-colored heron. Piping plovers, a threatened species, and Wilson's plovers, a significantly rare species, are also found on the Currituck Banks component (NCNHP 2008). Currituck Sound is located within the Atlantic Flyway and the site is especially important for migrating waterfowl.

Issues

There are several unique pressures and issues associated with managing the Currituck Banks component. Populations of feral pigs and horses are present on the site and can stress the native ecosystems of the site. Invasive *Phragmites australis* (Common reed) is also present and poses a risk to native marsh communities. Off-road vehicles, which are driven on the beach side of the site, can have great impacts on the site, including disruption of colonial nesting birds and enhancement of erosion. Enforcement of the Reserve's visitor use policies on the site is an issue. Public usage at all four Reserve components has increased over time resulting in the need for additional enforcement of the visitor use policies. Enforcement of the Reserve's policies is provided by partner agencies which are hampered by limited resources. Changes in water quality and the salinity of Currituck Sound is also an issue of concern. Historically, Currituck Sound has switched between a saline environment and a freshwater environment, depending on the presence of an inlet opening in the barrier island. The last inlet closed in 1828. Since then, the system has been predominately freshwater, but recent human-induced landscape alterations have caused the salinity to increase. Increasing salinity along with a decrease in water quality has led to changes in the biological community (*e.g.* loss of largemouth bass and submerged aquatic vegetation), causing profound impacts on species diversity and community composition. The largest and perhaps most challenging issue facing this Reserve component is development of nearby land areas and the resulting increase in stormwater runoff that will ensue and the increased pressure the Reserve will face for access to developed areas north of the site.

Program Priorities

The program priorities for Currituck Banks include in order: stewardship, community education and outreach/Coastal Training Programs/research and monitoring, and K-12 education. Stewardship is the highest priority because of the issues at the site and the expertise of staff managing the site. There is a medium priority for community education and Coastal Training programs. The recent addition of a boardwalk with interpretive signs makes the site more accessible and provides more opportunities for public interpretive field trips and public access. Coastal Training Programs are hosted in the area a few times a year, often in a workshop series, with the same training occurring in the central and southern parts of the state. Both of these programs provide opportunity to build understanding within the community regarding what the Reserve is and its purpose as well as promoting proper stewardship for better protection of the site and its environs. Research and monitoring is a medium priority activity given the capacity the site has for such activities, local partners, and recent activities. External funding was utilized from 2005 to 2007 to conduct component I SWMP monitoring at Currituck Banks. While limited in nature, this effort provided the first comprehensive multi-year water quality dataset for Currituck Banks which can be compared with future monitoring efforts. Additionally, atmospheric deposition and nutrient monitoring have also occurred at the site. K-12 educational programs are a low priority at Currituck Banks. Occasional site visits from professional development educator workshops, K-12 teacher field trips, and student field trips occur here, often with assistance from local stewardship staff.

b. Rachel Carson

Location and Description

The Rachel Carson component is located near the mouth of the Newport River in southern Carteret County, directly across Taylor's Creek from the historic Town of Beaufort (Figure 8). The 2,315-acre site consists of several small islands (Carrot Island, Town Marsh, Bird Shoal, Horse Island, and Middle Marsh) and extensive salt marshes and intertidal and subtidal flats. The Rachel Carson component is part of the NCNERR because of its extensive pristine salt marshes and intertidal/subtidal flats, which are ideal nursery areas for estuarine species. One of the two State ports, Morehead City, is located three miles to the west. Rachel Carson is bounded to the north by Taylor’s Creek and the Town of Beaufort, to the east by Back Sound, to the south by the Cape Lookout National Seashore, and to the west by Pivers and Radio Islands (Figure 8). The Rachel Carson Reserve is located in the White Oak River Basin which is located in the Carolinian biogeographical province. The site is accessible only by boat. The state Wildlife Resources Commission (WRC) operates a public boat ramp and parking lot along Taylor's Creek at Lennoxville Road. Several private ferry companies offer access to the island from Beaufort. A walking trail is available on the west end of Town Marsh and a boardwalk with interpretive signs is located on the east end of Carrot Island across from the WRC’s Lennoxville Road boat ramp in the Town of Beaufort.

The Rachel Carson component core areas consist of sound waters, tidal flats, creeks, and marshes that occur within the five islands that comprise the site: Middle Marsh, Carrot Island, Town Marsh, Bird Shoal, and Horse Island (2,107 acres). The primary example of

buffer area within the component is the dredge material deposits along Taylor's Creek on the north edge of the complex. There are also areas of beaches, dunes, shrub thickets, and a remnant of maritime forest at the east end of Carrot Island in the buffer area. These buffer areas total 208 acres.

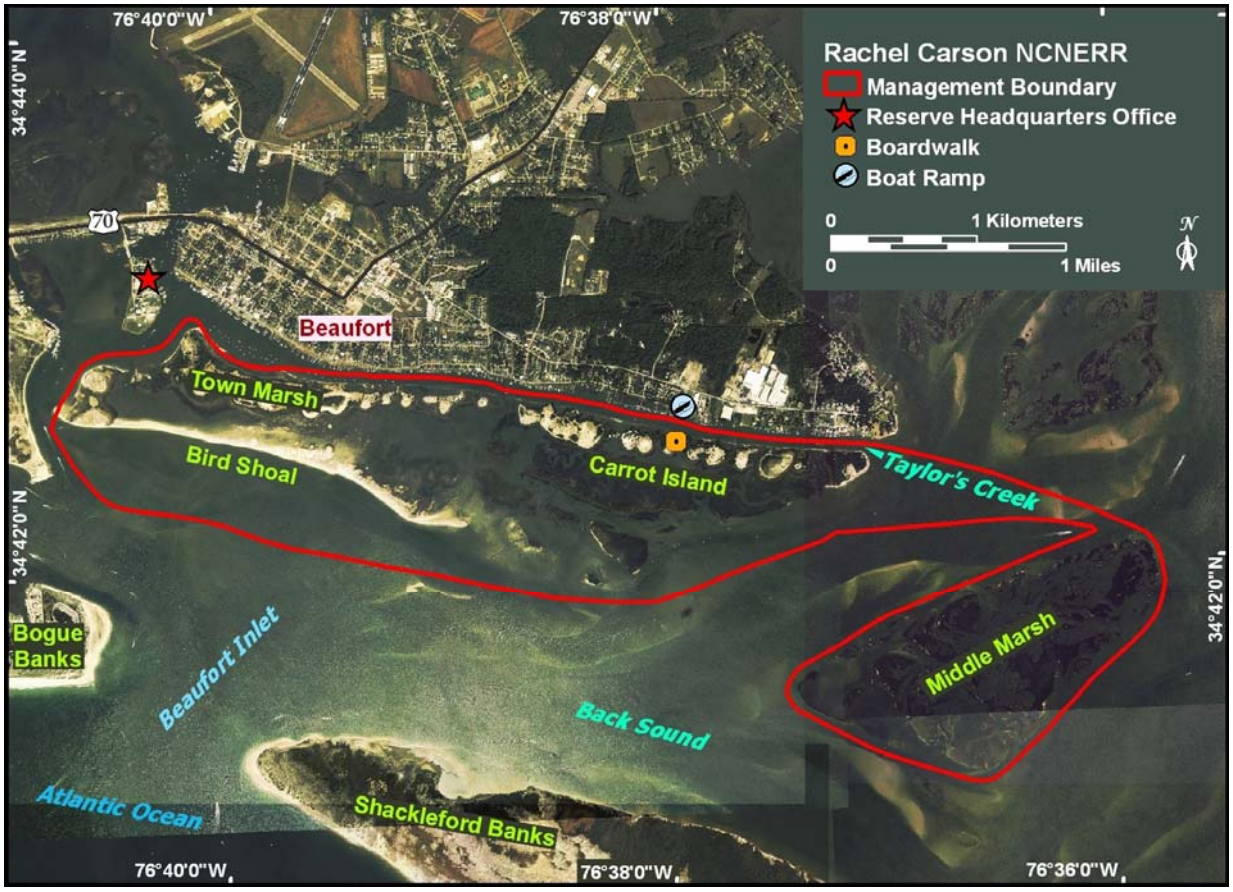

Figure 8: Rachel Carson site map

The islands and tidal flats comprising Rachel Carson consist of Recent (less than ~11,550 years old) and Pleistocene (1.8 million to ~ 11,550 years ago) sediments (Atkinson et al. 1998). Unlike the other components that make up the NCNERR, Rachel Carson is not a true barrier island. The underlying sediments are from a relict flood tide delta from a now closed inlet. These sediments raised the estuarine bottom enough to produce several shoals and small islands. Over time this area was colonized by marsh plants which stabilized the sediments. During the 1930s the Army Corps of Engineers placed spoils from the dredging of Taylor’s Creek on areas of these shoals. These areas now make up the upland portions of the Reserve, which provide habitat for many upland plant and animal species.

The area around the Rachel Carson site is a center of marine research and education. The marine laboratories of Duke University, University of North Carolina at Chapel Hill, and North Carolina State University are located here, as is the NOAA’s Center for Coastal Fisheries and Habitat Research. The headquarters of the North Carolina Divisions of Coastal Management and Marine Fisheries are also located in nearby Morehead City.

The islands and estuarine waters at the Rachel Carson site are strongly influenced by river and inlet dynamics and twice-daily tides. The site is an important feeding area for Wilson's plovers in the summer and piping plovers in the winter. The shrub thicket of Middle Marsh supports an egret and heron rookery. In addition to feral horses, gray fox, raccoon, and marsh rabbit inhabit the islands. The Atlantic bottlenose dolphin swims in the waters around the islands, along with many species of fish.

Issues

There are several unique pressures and issues associated with managing the Rachel Carson component. Since all upland areas of the site are man-made dredge spoil deposits, an opportunity to study the stability of man-made islands in relation to natural processes exists. A study of plant succession on the dredge spoil deposits is of interest since the Army Corps of Engineers maintains a dredge spoil easement on the Reserve site. This easement presents an ongoing management challenge since the dredge spoil deposits destroy existing natural communities and it take decades for plant succession to occur on the deposits due to high soil salinities. In addition, surrounding estuarine environments may be at risk due to increased sedimentation from deposition material. A survey of the islands on the east end has revealed an erosion rate of about 3.25ft y^{-1}. A living shoreline will be installed at this location as part of a collaborative estuarine shoreline stabilization project to test the efficacy of this type of structure in a highly erosive environment. The Rachel Carson site is also home to a resident population of feral horses. These horses, the descendents of a domestic population once owned by a Beaufort resident, are isolated on the island and thus provide a chance to study the impact of these animals on a coastal island ecosystem. The town of Beaufort's wastewater treatment plant's sewage outfall is located in the waters adjacent to the Rachel Carson component. Occasional raw sewage overflows occur from this facility and result in shellfish bed harvesting closures and swimming advisories. There are several invasive species found on the islands of the Rachel Carson site, including Tamarisk tree (or salt cedar, *Tamarix sp.*), Russian olive (*Elaeagnus sp.*) and nutria (*Myocastor coypus*). For more information regarding these and other issues please see the NCNERR site profile. Finally, enforcement of the Reserve's visitor use policies on the site remains an issue of concern. Public usage at the Rachel Carson component has increased over time resulting in the need for additional enforcement of the visitor use policies. The enforcement of the Reserve's policies at all sites is provided by partner agencies which have limited time and resources to devote to this effort. Enforcement of this site is particularly difficult because of boat and staffing resources.

Program Priorities

Since all of the Reserve's education resources are located in Beaufort, K-12 student and teacher education, community education and outreach, and Coastal Training Program activities are the highest priority for this site. There are numerous opportunities for the interpretation of this site for K-12 and public audiences, including a walking trail, public field trips, summer camps, and a boardwalk with interpretive signs on Carrot Island. The site is easily accessible by boat from the Town of Beaufort and the Reserve office on Pivers Island. Additionally, there are two water taxi vendors that service the Rachel Carson component, which enables school groups and the public to easily access the islands. Many Coastal Training Program activities are also conducted in the area near the Rachel Carson component. Both stewardship and research and monitoring programs are medium priorities for the site. The site is routinely used for field studies by local academic and government institutions including the Duke University Marine Laboratory, NOAA's Center for Coastal Fisheries and Habitat Research (CCFHR), and the University of North Carolina-Chapel Hill's (UNC-CH) Institute of Marine Sciences (IMS). SWMP component I was initiated at the Rachel Carson component in the mid-1990s. This was the first attempt to expand the monitoring to Reserve components outside the Wilmington area. This effort was discontinued in 2003 when the staff position needed to maintain the monitoring equipment was cut for budgetary reasons. A recent partnership between the National Park Service and the NCNERR reestablished SWMP component I monitoring at the Rachel Carson Reserve in 2007 and is ongoing. Stewardship of the site is important because of the heavy use by outside researchers and the high seasonal visitation.

c. <u>Masonboro Island</u>

Location and Description

Masonboro Island is the largest NCNERR component and was designated in 1991. It is located in New Hanover County between the barrier island towns of Wrightsville Beach and Carolina Beach (Figure 9). It is bounded by Masonboro Inlet to the north, the Atlantic Ocean to the east, Carolina Beach Inlet to the south, and Masonboro and Myrtle Grove Sounds (part of the Atlantic Intracoastal Waterway) to the west. The city of Wilmington lies approximately five miles to the northwest. Masonboro Island is the largest undisturbed barrier island along the southern part of the North Carolina coast and is located within the Carolinian biogeographic province. It is approximately 8.4 miles (13.5 km) long and the management boundary encompasses 5,653 acres (20.4 km^2) of subtidal soft bottoms, tidal flats, salt marshes, shrub thicket, maritime forest, dredge spoil areas, grasslands, ocean beach and sand dunes. Masonboro Island is the only NCNERR component that has in-holdings (privately owned property) within the management boundary. There are 12 remaining privately owned properties totaling approximately 17 acres of Masonboro Island proper.

Masonboro Island is only accessible by boat. Similar to the Rachel Carson Reserve, private operators provide fee-based ferry service to the Reserve site. Most visitors land on the sound side of the northern and southern ends of the island where there are large sandy beaches. Many other landings on the sound side within the middle portion of the island are only accessible at or near high tide.

Masonboro Island is included in the NCNERR because it is the largest undisturbed barrier island along the southern part of North Carolina, which provides an ideal location to study natural barrier island geological movement and its effect upon biological community assemblages. The back-island sounds plus associated tidal creeks and salt marshes occupy a core area of 4,194 acres. Masonboro Island proper and spoil islands along the Intracoastal Waterway constitute the buffer area (1,459 acres). Habitats within these areas include ocean beaches, dunes, shrub thicket, and maritime forest. The buffer area also includes 50 acres owned by University of North Carolina-Wilmington (UNCW) located across the waterway from the island. This is the site of the Reserve office, housed at UNC-Wilmington's Center for Marine Sciences, for the Masonboro Island and Zeke's Island components (Figure 9).

The Masonboro Island component consists of Recent (less than ~11,550 years old) and Pleistocene (~1.8 million to ~11,550 years before present) sediments (Atkinson et al. 1998, Moorefield 1978). The upland areas include natural and dredge spoil built areas. These are mostly found on the back side of the island adjacent to the Intracoastal waterway. Masonboro Inlet is stabilized by jetties and the northern end of Masonboro routinely receives spoil deposits from inlet dredging via a U.S. Army Corps of Engineers easement. Carolina Beach Inlet, at the southern end, is an artificially created waterway to enhance boater access to the Atlantic Ocean.

Masonboro Island supports a myriad of estuarine species. Loggerhead and green sea turtles nest on the beaches, where seabeach amaranth plants grow on the foredunes. All of these species are listed as threatened by the Federal government. Other species of concern are black skimmers, Wilson's plovers, and least terns all of which routinely utilize Masonboro Island for nesting. The waters of Masonboro Sound are an important local source of shellfish and serve as an important nursery area for numerous finfishes including spot, mullet, summer flounder, pompano, menhaden, and bluefish.

Issues

There are several unique pressures and issues associated with managing the Masonboro Island component. One issue is that inholdings, or portions of the Island owned by private entities, remain within the management boundary. It is difficult to manage a site appropriately when properties within the management area are privately owned. Inappropriate visitor use of the Island is also a major management problem. Visitor use issues associated with the Island include irresponsible camping, litter, and theft of personal boating equipment. Excessive alcohol use and partying are also recurring problems. Visitor use issues are greater at this Reserve site than others due to Masonboro Island's close proximity to the city of Wilmington and the Intracoastal Waterway. As the coastal population has increased so has the public usage at this Reserve component resulting in the need for additional enforcement of the visitor use policies. Enforcement is difficult due to limited resources of the Reserve's partnering agencies and due to the fact that the site can only be accessed by boat and boat and staffing resources are limited. Masonboro Island is also affected by occasional raw sewage contamination from failures in or disturbances to the city of Wilmington's sewer system. This sewage contamination can result in shellfish bed harvesting closures and swimming advisories. Additionally, dredge spoil is routinely deposited on the Island to ameliorate the loss of sediment transport and natural buildup due

to the hardening of Masonboro Inlet. This application of dredge spoil can disrupt colonial nesting birds and sea turtle nesting. Invasive species are also an important management issue for Masonboro Island. Recently, beach vitex (*Vitex rotundifolia*) has been found on Masonboro. This plant has tremendous potential to displace native dune species and destroy sea turtle nesting habitat.

Figure 9: Masonboro Island site map

Program Priorities

Research and monitoring, stewardship, and community education are the highest priorities at the Masonboro Island component. Two of the long-term SWMP stations and the weather station are located at this site. Additionally, the site is used regularly by researchers at UNCW. Stewardship is a high priority at the site as a result of the high seasonal visitation and misuse by some visitors. Stewardship activities have increased on the Island with the addition of the Southern Sites Manager in 2005, including sea turtle nest monitoring and delineation of colonial nesting shorebird habitat. Community education is also a high priority at the site because of the high visitation and misuse, yet the Reserve does not currently have the resources to adequately implement a robust community education program. Coastal Training Program activities are a medium priority for Masonboro due to the close proximity of the large population center of Wilmington. Coastal Training Programs are hosted in the Wilmington area a few times a year, often in a workshop series, with the same training occurring in the northern and central parts of the state. K-12 educational programs at Masonboro Island are a low priority, primarily because the site is only accessible by boat and transportation of large groups to the site is difficult. Some student field trips, student field studies, professional development educator workshops, and teacher field trips do occur here, with help from the Wilmington Reserve office staff.

d. Zeke's Island

Location and Description

The Zeke's Island component of the NCNERR is located in portions of both Brunswick and New Hanover counties, in southeastern North Carolina just south of Kure Beach (Figure 10). The nearest population center is Wilmington, N.C. located 22 miles (35 km) to the north. Southport, N.C. is located across the Cape Fear River 10 miles (16 km) to the south-southwest. Zeke's Island is bounded to the north by Federal Point (encompasses Fort Fisher State Park and the North Carolina Aquarium at Fort Fisher), to the east by the Atlantic Ocean, the Cape Fear River to the west, and the Smith Island Complex to the south. Zeke's Island is located in the Cape Fear River basin and on a broader scale is located in the Carolinian biogeographic province. Zeke's Island is accessible by both foot traffic and boat. A boat ramp is present at the northern end of the Reserve providing nearby boat access to the 1,635 acre Reserve (Figure 10). Walking trails overlooking the Reserve are provided through a partnership with the North Carolina Fort Fisher State Park.

The boundary line for the Zeke's Island component on the west is a late 19th century rock jetty. The jetty was installed as a sediment control structure to minimize shoaling of the shipping channel in the Cape Fear River. The area to the east of the jetty has become lagoonal in nature (Figure 10). The core area in the Zeke's Island component is 1,411 acres of estuarine habitats with tidally influenced basin waters, creeks, and intertidal and supratidal marsh communities. The buffer areas for the Zeke's Island component comprise 224 acres, of which 39 acres is ocean beach habitat along the Atlantic Ocean shoreline. Buffer areas also include 185 acres of upland habitats distributed between Zeke's Island (14 acres), North Island (76 acres) and the barrier spit (95 acres) along the Atlantic Ocean. Zeke's Island has

elevations of only several feet. North Island has several scattered dune systems, one of which reaches to twenty feet above sea level.

Figure 10: Zeke's Island site map

The Zeke's Island component contains surface sediments representative of the coastal plain. These sediments are varying combinations of sand, silt and clay, from terrestrial and marine sources. Some of these deposits are considered Recent (less than ~11,550 years old) and some are of Pleistocene (~1.8 million to ~11,550 years before present) origin (Atkinson et al. 1998, Moorefield 1978). The Pleistocene deposits are thin blankets of marine and estuarine sands and clays occurring in a series of terraces and scarps related to previous shoreline locations. These deposits overlay layers of Cretaceous (~140 to ~70 million years before

present) and Tertiary (~70 to ~1.8 million years before present) terrigenous and carbonate deposits (Atkinson et al. 1998, Moorefield 1978).

The Cape Fear region is representative of coastal cape formations along North and South Carolina. Shoals often extend seaward from these cape areas. Frying Pan Shoals extends seaward from the Cape Fear estuary area outward to approximately 31 miles (50 km). Barrier island formations generally extend north and southwest off these cape regions. The accepted theory is that the capes have maintained their basic positions and morphologies throughout the Pleistocene and Holocene (~11,550 years ago to present) by migrating landward or seaward in response to sea level changes (Moorefield 1978).

Ocean inlets have historically formed, migrated, and closed within the barrier-spit area of Zeke's Island. The last oceanic inlet in this area, New Inlet, closed in March 1999 (Cleary & Marden 2001). Currently water exchange is dependent on the adjacent Cape Fear River. Coastal processes continue to change and rework the beach environments that produce the barrier island and estuarine features found around Zeke's Island.

The unusual characteristics of the site have created a variety of habitats, including tidal flats, salt marshes, shrub thicket, maritime forest, sand dunes, ocean beach, and the hard surface of the rock jetty. The surrounding estuarine waters are highly productive and used regularly for sport/commercial fishing and recreational purposes. Fish, shrimp, crabs, clams, and oysters also use the estuary as a nursery ground. Both the Atlantic loggerhead and green sea turtles, federally protected threatened species, occasionally nest on the site's open beaches. Seabeach amaranth, a threatened plant species, has also been found on the site's foredune areas.

Issues

There are several unique pressures and issues associated with managing the Zeke's Island component. There is anecdotal evidence from fisherman and other users of the component that there is increased sedimentation occurring around the site. Areas are silting in and water depths are much shallower than what they were ten years ago. There are also several visitor use issues including litter, safety (people walking along the jetty), and access (people disturbing research plots). Similar to the other components, enforcement of the visitor use policies at Zeke's Island remains an issue of concern. Beach Vitex (*Vitex rotundifolia)* has also been found within Zeke's Island. This will certainly become a very important management issue within the next 5 years. Changing water quality of the Cape Fear River is also a great concern for this Reserve. The Cape Fear River is the largest river basin within N.C. and drains approximately 23,310 km^2 through 100 counties.

Program Priorities

Research and monitoring is a high priority for the Zeke's Island component because of the long-term location of two SWMP stations at the site. K-12 educational programs are a medium priority at Zeke's Island because part of the component is on the mainland and may be accessed by foot and boat, facilitating easy access by large groups. The focus of these programs is student field trips, student field studies, professional development educator

workshops, and teacher field trips conducted with help from the Wilmington Reserve office staff. Stewardship of the site is a medium priority given the presence of the Stewardship Coordinator at the Wilmington office and the species monitoring that occurs at the site. Coastal Training Programs are hosted in the Wilmington area a few times a year, often in a workshop series, with the same training occurring in the northern and central parts of the state. Community education is a lower priority at the site given the close proximity of the Fort Fisher Aquarium and State Park.