Appendix 1: NERRS Strategic Plan

strategic PLAN | 2005 - 2010

National Estuarine Research Reserve System

research stewardship education

Appendix 1: NERRS Strategic Plan

The National Estuarine Research Reserve System is administered by NOAA's National Ocean Service, Office of Ocean and Coastal Resource Management, Estuarine Reserves Division. For more information, visit us online at **www.nerrs.noaa.gov** or contact us at: 1305 East West Highway N/ORM5, Silver Spring, Maryland 20910. Phone number: 301-713-3155

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vision | Healthy estuaries and coastal watersheds where coastal communities and ecosystems thrive.

mission | To practice and promote coastal and estuarine stewardship through innovative research and education, using a system of protected areas.

goals

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 peoples' ability and willingness to make informed decisions and take responsible actions that affect coastal communities and ecosystems.

Introduction

For thousands of years, coastal and estuarine environments have provided people with food, safe harbors, transportation access, flood control, and a place to play and relax. The pressures on the nation's coast are enormous and the impacts on economies and ecosystems are becoming increasingly evident. Severe storms, climate change, pollution, habitat alteration and rapid population growth threaten the ecological functions that have supported coastal communities throughout history. As a network of 27 protected areas established for long-term research, education and stewardship, the National Estuarine Research Reserve System (NERRS) has a unique role to play in keeping coastal ecosystems healthy and productive.

The reserve system is a partnership program between the National Oceanic and Atmospheric Administration and coastal states that has protected more than one million acres of coastal and estuarine habitat since the program was established by the Coastal Zone Management Act in 1972. NOAA provides funding, national guidance and technical assistance. Each reserve is managed on a daily basis by a lead state agency, non-profit organization or university with input from local partners. Through careful stewardship, innovative science and education, and relevant training programs, the reserves encourage careful management and protection of local estuarine and coastal resources.

The Coastal Zone Management Act created the reserve system to protect estuarine areas, provide educational opportunities, promote and conduct estuarine research and monitoring, and transfer relevant information to coastal managers. For the next five years, core reserve programs will focus on four priority topics: impacts of land use and population growth, habitat loss and alteration, water quality degradation, and changes in biological communities. The National Estuarine Research Reserve System's 2005-2010 Strategic Plan articulates how the strengths of the reserve system will be applied to address the major challenges of coastal management.

A Local Approach to National Priorities

Land use and population growth, water quality degradation, habitat loss and alteration, and changes in biological communities are not the only topics that reserves work on, but these four have risen to the top as deserving of adequate and strategic investment for the national system. These four topics are high priority science and training needs for coastal managers.[3] Reserve scientists, educators and land managers have identified these topics as locally and nationally important and appro-

priate to the mission of the National Estuarine Research Reserve System. Increased understanding about these topics will improve the reserve system's ability to protect and restore coastal watersheds and estuaries and empower individuals to make informed decisions. The nation's coasts and estuaries need to be managed, understood and appreciated at multiple scales. Through a network of locally oriented programs around the country, the reserve system provides insight into common information and management needs as well as data for use by local, regional and federal scientists and decision makers. Working at both the site level and as a national system, reserves have a greater impact than could be achieved through community efforts alone.

The goals, objectives and strategies outlined in this strategic plan will guide and support the National Estuarine Research Reserve System in its nation-wide efforts to improve coastal management, advance estuarine research, and educate current and future generations of coastal stewards.

Stewardship: | *The responsible management of coastal resources using the best available information for the purpose of maintaining and restoring healthy, productive and resilient ecosystems.*

Priority Coastal Management Issues

1. Land Use and Population Growth

The United States' exploding coastal population results in competing demands for clean water, beaches, recreational and commercial space, infrastructure and housing. In 2003, an estimated 153 million people lived in coastal counties, which is approximately 53% of the total US population. Pressure to develop land in coastal areas is escalating at more than twice the rate of population growth. Land use changes can significantly impact coastal and estuarine species and habitat. The Pew Ocean Commission reports that when more than 10% of a watershed is covered in impervious surface such as roads, roofs and parking lots, aquatic resources begin to degrade.[1]

Coastal population and land use demands are not only increasing, they also are changing. Demographic and socio-economic trends show that the backgrounds and interests of people who are moving to the coast may be different from those of traditional fishing, commerce, or beach communities. The way people value and understand their relationship to the coast is reflected in the personal, political and professional choices they make. To make wise coastal resource management decisions, we need to understand the relationships among estuarine ecosystems and changing landscapes and attitudes. National Estuarine Research Reserves encourage the development and use of science based knowledge and tools in local land use planning, community development, and stewardship of public and private property.

2. Habitat Loss and Alteration

More than half of the nation's coastal wetlands have vanished since European settlement.[2] Estuarine and coastal environments continue to be altered and eliminated due to dredging, dams, recreational and commercial uses, flood and hazard mitigation, residential and infrastructure development, commercial port activities, and agriculture. Many of these activities disturb the physical, biological and chemical attributes of the estuary and therefore degrade

the plants and animals that depend on the habitat to survive. Seagrass beds, marshes, shellfish, bird and fish populations can be affected by sedimentation, erosion, and hydrological, chemical or physical alteration of the habitat. Estuarine ecosystems also are vulnerable to coastal storms and sensitive to changes in climate and sea level. Coastal managers want to know more about how their choices influence coastal habitat and the species that live there. Better information will ensure that alternatives are considered for permitting, as well as planning and implementing successful restoration and mitigation efforts.[3]

Reserve research and monitoring programs increase the fundamental understanding of estuarine dynamics and add new information about the causes and consequences of changes in habitat quantity and quality. Research and stewardship programs at the NERRs also develop, implement and evaluate new techniques to restore and protect estuarine resources. Training programs and advisory services make this information available to professionals. Through education programs conducted at the reserves, students and citizens learn why these habitats are important and what they can do to keep them healthy.

3. Water Quality Degradation

Improving the condition of coastal water quality is a goal of the Coastal Zone Management Act and an ongoing struggle for all coastal regulatory agencies. Despite continuing local, state and federal investments, more than 20,000 beach closures were enforced in 2004[4] and more than 60% of estuarine waters were classified by the EPA as having degraded water in 2005.[5] Excess nutrients and chemical and biological contamination can cause human health problems and threaten aquatic life.

The Reserve System has been collecting water quality data for ten years to quantify short term variability and long term changes in estuarine waters. Through monitoring and studying changes in water quality, the reserves investigate how human activity, weather patterns, and estuarine characteristics contribute to changes in water quality that affect ecological processes and, consequently, human health. Reserves apply the knowledge generated through research and monitoring to improve water quality through habitat protection, restoration, and training and outreach programs.

4. Changes in Biological Communities

Biological communities are changing as a result of invasive species, over-harvest, climate changes, pollution, and habitat destruction. Invasive species out-compete or consume native organisms; habitat alteration and destruction displace some species and create opportunities for others; and changes in parameters such as temperature and salinity can shift the distribution of plants and animals. Chemical contamination and nutrient enrichment damage habitat and can alter the structure of floral and faunal communities. Over-harvesting biological resources also can change community structure and threaten valuable species. These problems impact natural interactions and linkages and lead to cascading indirect effects throughout the ecosystems.

Reserve research, stewardship, education, and training programs focus on understanding how changes in biological communities affect the way estuaries function. To minimize the negative impact of these changes, reserves investigate and communicate how to balance public needs with the protection of increasingly susceptible natural resources.

Guiding Principles

- Strong partnerships between NOAA, state agencies and universities, and other local partners are critical to the success of the reserve system.
- The reserve system integrates science, education and stewardship on relevant topics to maximize the benefits to coastal management.
- Reserves serve as a catalyst and a focal point for demonstrating and facilitating objective problem solving and best management practices.
- Reserves engage local communities and citizens to improve stewardship of coastal areas.
- Reserves implement an ecosystem-based management approach.

Goal One:

Strengthen the protection and management of representative estuarine ecosystems to advance estuarine conservation, research and education.

Objectives:

1. Biogeographically and typologically representative estuarine ecosystems are protected through the designation of new reserves.

2. Biological, chemical, physical, and community conditions of reserves are characterized and monitored to describe reference conditions and to quantify change.

3. Reserve ecosystems are conserved through land acquisition, natural resource management and restoration.

Strategies:

- Identify and designate new reserves consistent with system-wide policy and available resources.

- Collect system-wide measurements of the short-term variability and long-term changes in the water quality, biotic communities and diversity, land-use and land cover characteristics of estuarine ecosystems to support effective coastal zone management.

- Collect baseline information about the biological, physical, chemical, and socio-economic parameters of reserve biological and human communities.

- Integrate NERRS monitoring, data management, education and training capabilities in regional ocean observing systems.

- Implement land acquisition plans to enhance the long term integrity and diversity of reserve habitats.

- Restore and actively manage reserves' natural resources to meet local habitat and human use goals.

- Work collaboratively with other programs to evaluate and apply advanced technologies and tools to support effective coastal management.

- Provide facilities and support to manage the natural resources within reserve boundaries.

Goal Two:

Increase the use of reserve science and sites to address priority coastal management issues.

Objectives:

1. Scientists conduct estuarine research at reserves that is relevant to coastal management needs.
2. Scientists have access to NERRS datasets, science products and results.
3. The scientific community uses data, tools and techniques generated at the NERRS.

Strategies:

- Understand coastal decision maker science and training needs through needs assessments, coastal management science needs surveys, etc.
- Work collaboratively with other programs to conduct research on priority management issues in the reserves.
- Offer Graduate Research Fellowships to master's and doctoral students to conduct science that is relevant to coastal management and to train students in estuarine science.
- Deliver monitoring and observation data to the scientific community.
- Disseminate reserve science through publications, outreach and technology transfer.
- Generate time-series data and empirical studies to describe the ecological condition of reserve habitats.
- Promote reserve science products through web sites, communication materials, and other avenues to meet the needs of diverse stakeholders.
- Increase visibility and reinforce the credibility of NERRS science through communication efforts about NERRS research and monitoring.
- Attract scientists and practitioners to use reserves as reference sites.
- Conduct and facilitate relevant research in reserve watersheds.
- Synthesize reserve data into information for use in decision making.
- Conduct and facilitate research into education effectiveness and behavior change.
- Ensure that reserves have facilities and research support to meet the needs of visiting scientists and staff.

Scientist: *A person who uses principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.*

Goal Three:

Enhance people's ability and willingness to make informed decisions and take responsible actions that affect coastal communities and ecosystems.

Objectives:

1. People are aware of the ecological, economic, historical, and cultural importance of estuarine resources.

2. People understand how human choices and natural disturbances impact social, economic, and estuarine ecological systems.

3. People apply science-based information when making decisions that could impact coastal and estuarine resources.

Strategies:

- Provide educational opportunities that increase students' understanding of estuarine science and technology.

- Implement and participate in public programs and events to raise awareness and understanding about estuaries and the NERRS.

- Produce and distribute educational materials and web-based products that raise public awareness about estuaries, the NERRS, and NERRS education products.

- Train teachers to educate students about coastal watersheds and estuaries.

- Deliver monitoring and observing data to diverse user groups in a useful format.

- Improve the willingness and ability of communities to restore and protect coastal ecosystems.

- Provide science-based information and training to individuals and organizations.

- Assist restoration practitioners in developing and applying effective restoration techniques.

- Implement volunteer programs to engage local citizens in advancing the goals of the reserves.

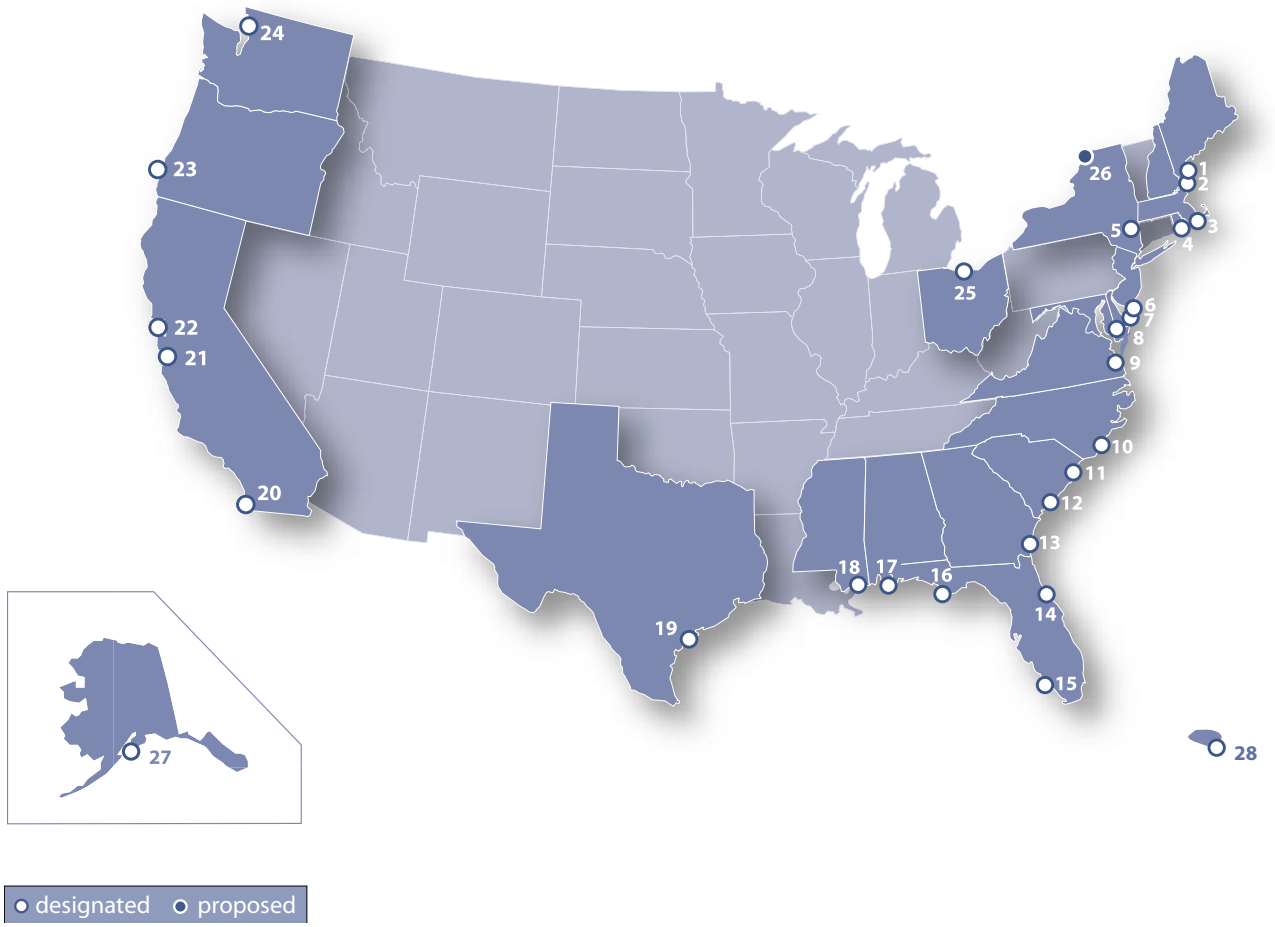
- Conduct programs to encourage people to make personal choices that reduce their impact on coastal resources.

- Evaluate programs to determine how people apply information and knowledge.

- Build and maintain educational facilities and interpretive displays.

Sources

1. Pew Ocean Commission Report
2. United States Commission on Ocean Policy Report
3. NERRS Coastal Training Program Trends Analysis Report, Improving Links Between Science and Coastal Management
4. National Resource Council website
5. EPA Coastal Conditions Report



1. Wells Reserve, Maine
2. Great Bay Reserve, New Hampshire
3. Waquoit Bay Reserve, Massachusetts
4. Narragansett Bay Reserve, Rhode Island
5. Hudson River Reserve, New York
6. Jacques Cousteau Reserve, New Jersey
7. Delaware Reserve
8. Chesapeake Bay Reserve, Maryland
9. Chesapeake Bay Reserve, Virginia
10. North Carolina Reserve
11. North Inlet-Winyah Bay Reserve, South Carolina
12. ACE Basin Reserve, South Carolina
13. Sapelo Island, Georgia
14. Guana Tolomato Matanzas Reserve, Florida
15. Rookery Bay Reserve, Florida
16. Apalachicola Reserve, Florida
17. Weeks Bay Reserve, Alabama
18. Grand Bay Reserve, Mississippi
19. Mission-Aransas, Texas
20. Tijuana River Reserve, California
21. Elkhorn Slough Reserve, California
22. San Francisco Bay, California
23. South Slough Reserve, Oregon
24. Padilla Bay Reserve, Washington
25. Old Woman Creek, Ohio
26. Proposed Reserve—St. Lawrence River
27. Kachemak Bay Reserve, Alaska
28. Jobos Bay Reserve, Puerto Rico

Appendix 2: NERRS Research and Monitoring Plan

National Estuarine Research Reserve System

Research and Monitoring Plan (2006-2011)

The National Estuarine Research Reserve System is administered by NOAA's National Ocean Service, Office of Ocean and Coastal Resource Management, Estuarine Reserves Division. For more information, please contact Susan White, Research Coordinator, NOAA Estuarine Reserves Division, at Susan.White@noaa.gov. Or, visit **http://www.nerrs.noaa.gov**.

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Executive Summary

This document: 1) describes the current status of research and monitoring efforts within the National Estuarine Research Reserve System (NERRS), 2) describes five research priority areas that the system will focus on over the next five years, and 3) outlines a set of strategies that will enable the system to move forward in conducting and supporting research to address specific coastal management needs as well as improve our basic understanding of estuarine systems.

The five priority research areas were identified with input from a variety of sources including reserve research staff and managers, the NERRS Strategic Plan, and national documents outlining national coastal research needs and priorities. NERRS priority research areas focus on:

- Habitat and Ecosystem Coastal Processes
- Anthropogenic Influences on Estuaries
- Habitat Conservation and Restoration
- Species Management
- Social Science and Economics

Key reserve research goals, objectives, and strategies presented in this research plan will assist the reserve system in addressing the five research priority areas, as well as meeting strategic goals outlined by the system, in the following five years. Social science and economics are disciplines that could engender relevant research related to the priority areas listed. The research goals outlined for this plan include:

Goal 1: Biological, chemical, physical, and ecological conditions of reserves are characterized and monitored to describe reference conditions and to quantify change.

Goal 2: Scientists conduct research at reserves that is relevant to coastal management needs and increases basic understanding of estuarine processes.

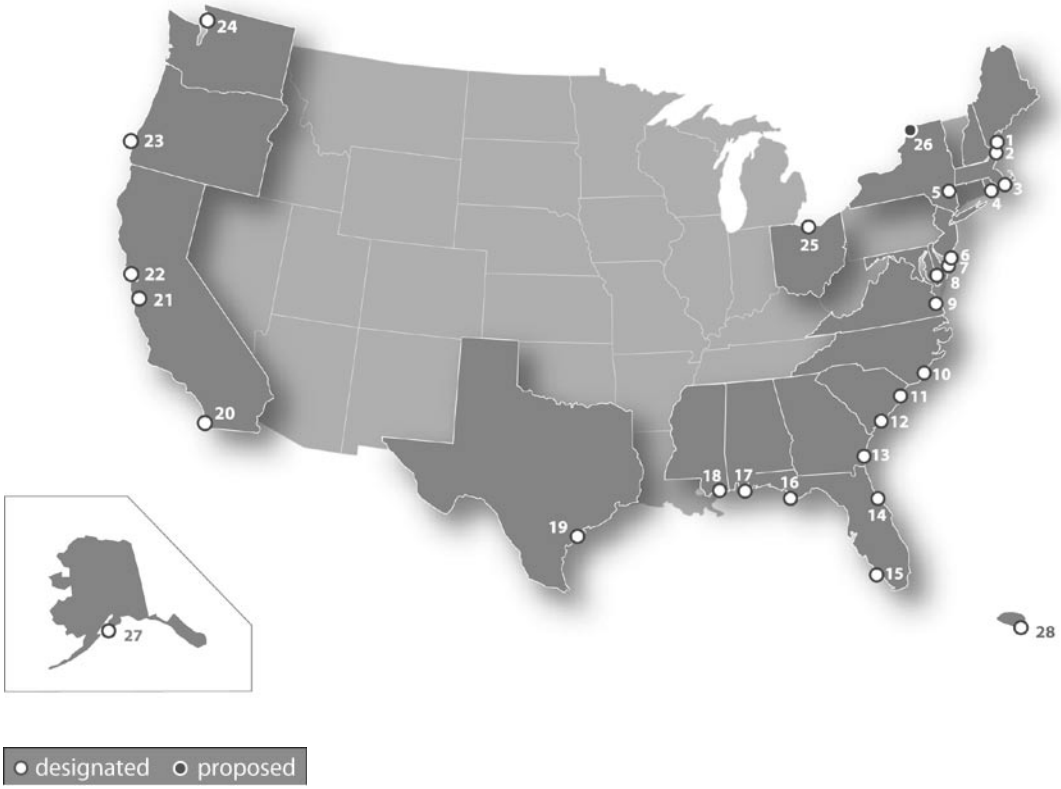
Goal 3: Scientists, educators, and coastal managers have access to NERRS datasets, science products and results.

Goal 4: The scientific, coastal management and education communities, as well as the general public, use data, products, tools, and techniques generated at the NERRS.

The NERRS has developed this research and monitoring plan to guide national, regional, and local research efforts that promote the protection and conservation of estuarine habitats through the provision of improved ecological information.

NATIONAL ESTUARINE RESEARCH RESERVES

A network of 27 protected areas



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Introduction

The National Estuarine Research Reserve System (NERRS) is a network of 27 reserves dedicated for long-term research, monitoring, education and resource stewardship. These 27 estuaries and coastal watersheds, representing different biogeographic regions of the United States, were established by the Coastal Zone Management Act of 1972. The reserve system operates as a partnership program between the National Oceanic and Atmospheric Administration (NOAA) and the coastal states and territories. NOAA provides funding, national guidance and technical assistance, while the states provide matching funds, personnel, and managerial oversight. Each reserve is managed on a daily basis by a lead state agency or university, with input from local partners. This partnership program between NOAA and the coastal states and territories protects more than 1.3 million acres of estuarine land and water, which provide essential habitat for wildlife; offer educational opportunities for students, teachers and the public; and serve as living laboratories for scientists.

One of the Guiding Principles of the Estuarine Reserves Division (ERD), as outlined by the NERRS Strategic Plan (2005-2010), is to "demonstrate and facilitate the development of sound science and best practices for improved local and regional coastal resource management." The reserve system is also mandated to provide protection of estuarine and coastal natural resources and to promote research and education activities that lead to greater protection of these systems. To facilitate the development of sound science for improved coastal decision making and the protection of natural resources, the reserve system has developed a research and monitoring plan that focuses on integrating the long term research goals of NOAA with those of the reserve system on local, regional, and national scales. As a system, the NERRS will approach research and monitoring from the perspective of an ecosystem approach to management which includes accounting for ecosystem knowledge and uncertainty, engaging in a collaborative and incremental approach to achieving research goals, employing adaptive techniques to improve research efforts, and balancing diverse environmental and societal objectives to inform coastal management decisions.

The purpose of this research plan is to help set priorities, provide a focus for partnership development, and help allocate financial resources and time to high priority issues. In addition, it will inform coastal resource managers and governmental, non-governmental, and academic scientists of the reserve system's research priorities and capabilities. This will serve to both enhance research collaborations and leverage resources to further the state of coastal research science to support improved coastal management. The research plan will also support reserve research, education, and stewardship staff in their efforts to seek

The National Estuarine Reserve System Research Plan

Audiences	Results
Scientists (governmental, non-governmental, and academic)	Communicates reserve research priorities
	Guides collaborative projects
Coastal resource managers	Leverages research resources within NOAA and external to the reserves

National Estuarine Research Reserve System

Vision: Healthy estuaries and coastal watersheds where human and ecological communities thrive.

Mission: To practice and promote coastal and estuarine stewardship through innovative research and education, using a system of protected areas.

external funding for reserve programs related to coastal resource management. As a living document, this five-year reserve research plan provides a basis for refining research priorities and strategies and also allows for the flexibility that is required to support a national research effort that is implemented primarily at local to regional scales. While this iteration of the plan focuses on natural science research, it is anticipated that this plan will be expanded to include research plans that address reserve needs in social science, restoration science, and education research within five years. Refining and aligning national, regional and local research priorities is challenging, yet efforts to do so will continually improve the relevance and impact of NERRS research efforts. While this research plan guides system-wide priorities, individual reserves will also pursue research and monitoring projects that address questions unique to their sites or regions. Reserve management plans will guide individual site-based research and monitoring priorities.

Background

The National Estuarine Research Reserves were established to provide opportunities for long-term research, education, and stewardship. According to 15 CFR Part 921 National Estuarine Research Reserve System Program Regulations, Subpart A, § 921.1 mission, goals and general provisions, three goals stand out as supporting the development of a coordinated research plan for the NERR system.

- Ensure a stable environment for research through long-term protection of NERR resources,
- Address coastal management issues identified as significant through coordinated estuarine research within the System, and
- Conduct and coordinate estuarine research within the System, gathering and making available information necessary for improved understanding and management of estuarine areas.

The authority to develop a system-wide research plan within the NERRS also resides in Title 16, Chapter 33, §1461 National Estuarine Research Reserve System, of the Coastal Zone Management Act (CZMA). Within the CZMA, specific research guidelines address the need for a plan for coordinated research and the development of related performance measures. Specifically, these guidelines suggest:

- Developing a mechanism for identifying, and establishing priorities among, the coastal management issues that should be addressed through coordinated research within the System,
- Establishing common research principles and objectives to guide the development of research programs within the System, and
- Establishing performance standards upon which the effectiveness of the research efforts and the value of reserves within the System in addressing the coastal management issues identified may be measured.

NOAA has recently redesigned its approach to research to follow a more interdisciplinary, cross-cutting strategy to address defined priority research areas (NOAA, 5-yr Research Plan, 2005). The new infrastructure for NOAA's research focuses on four mission goals: Ecosystem, Climate, Weather and Water, and Commerce and Transportation Goals. The reserve system is a strong contributing member of the Coastal and Marine Resources Program within the Ecosystems Goal Team. The reserve system also contributes indirectly to the Climate Goal as well as the Weather and Water Goal. The mission of the Ecosystems Goal is to protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management. Through the integrative and collaborative efforts of reserve research, education, and training activities, coastal ecosystems will be better understood and coastal decision making will improve.

National Oceanic and Atmospheric Administration

Vision: Societally relevant research that forms the scientific basis for more productive and harmonious relationships between humans and their environment.

Mission: To conduct research, develop products, provide scientific understanding and leadershipand to conduct outreach towards fostering NOAA's evolving environmental and economic mission.

NOAA's Ecosystem Goal Team Selected Outcomes

- **Healthy and productive coastal and marine ecosystems that benefit society.**
- **A well informed public that acts as stewards of coastal and marine ecosystems.**

Existing NERRS Research and Monitoring Programs

NERRS System-Wide Monitoring Program

The NERRS System-Wide Monitoring Program (SWMP; pronounced "swamp") was developed in 1995 to provide researchers, resource managers, educators, and other coastal decision makers quantitative measures with which to assess short-term variability and long-term change in estuarine conditions. At present, the program is moving into its second decade of collecting critical estuarine water quality and meterological data. A key feature in establishing SWMP was the implementation of a set of consistent standard operating procedures that ensure the long-term collection of data that is comparable across time and locations. As such, SWMP is able to provide robust data for such things as, for example, trend analysis and change detection of anthropogenic impact assessments, as well as the effects of large-scale forcing (e.g., El Niño/Southern Oscillation and North Atlantic Oscillation, climatic conditions, sea level rise, and global climate change) and localized, stochastic events (e.g., hurricanes and contaminant spills) on estuarine conditions within a reserve. By implementing these standard operating procedures in a coordinated fashion across all 27 reserves, SWMP data can also be used for meaningful comparisons of estuarine conditions at the regional and national levels, thus enhancing the value of the reserves as a system of national reference sites. Thus, SWMP provides valuable short- and long-term data to researchers, natural resource program managers, coastal educators, and other coastal decision-makers.

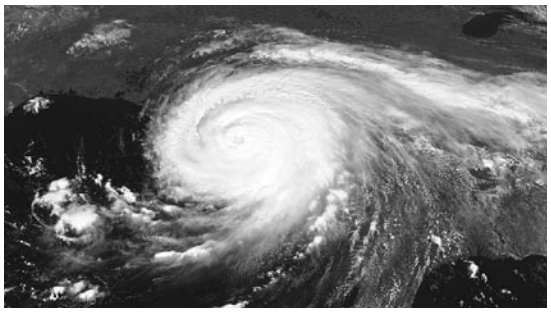


Photo Credit: NOAA's National Environmental Satellite, Data, and Information Service (NESDIS)

The NERRS System-wide Monitoring Program (SWMP) is able to provide both long-term data for trend analysis and change detection as well as data on the impact of localized, stochastic events such as Hurricane Katrina (2005) on estuarine conditions within reserves.

The NERRS and NOAA established SWMP as a phased monitoring approach that focuses on three different ecosystem characteristics:

Abiotic Factors, including: atmospheric conditions, water quality (nutrients, contaminants, etc.) and physical parameters (salinity, tidal range, groundwater, freshwater inflow, bathymetry, etc.);

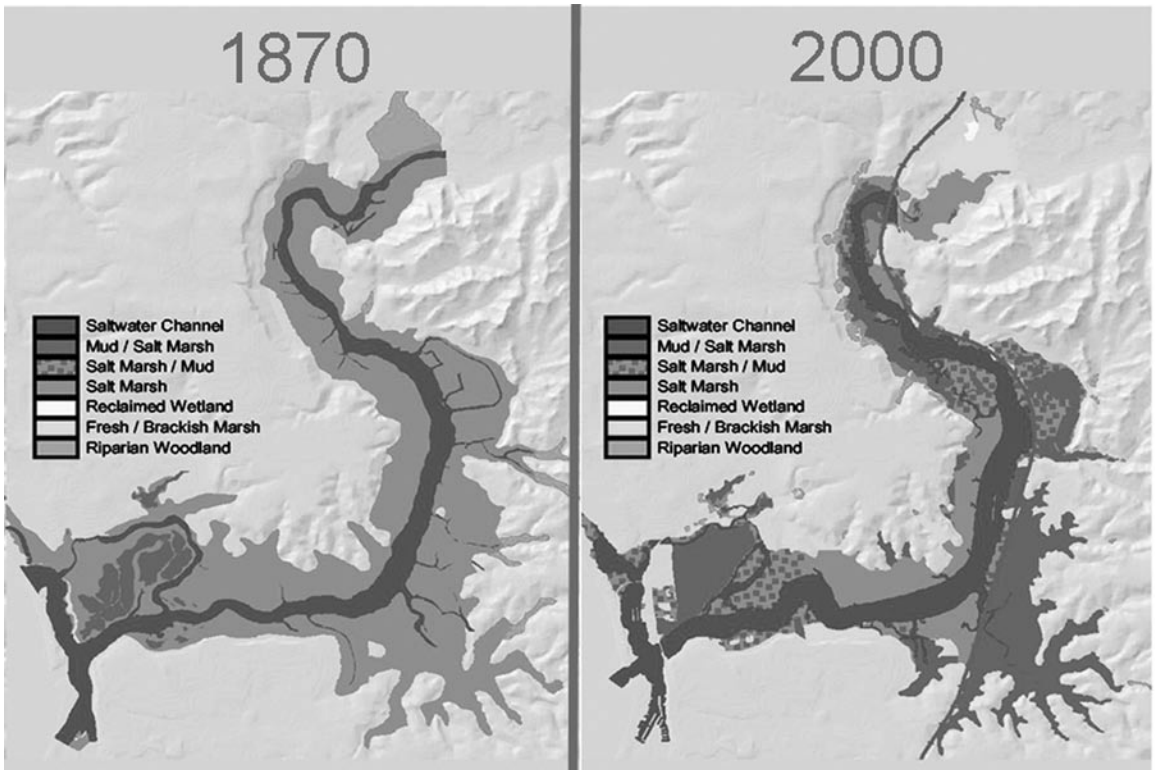
Biological Monitoring, including: biodiversity, habitat and population characteristics;

Watershed and Land Use Classifications, including: changes in consumptive and non-consumptive uses.

Phase 1 of SWMP focuses on monitoring a suite of water quality and meterological parameters over a range of spatial (local, regional, national) and temporal (minutes, hours, days, months, years) scales. Data loggers are continuously deployed at a minimum of at least four water quality stations at each reserve to record measurements of conductivity, salinity, temperature, pH, dissolved oxygen, turbidity, and water level at thirty minute intervals. Each reserve also collects monthly measurements of water column nutrients (e.g. nitrate, nitrite, ammonia, and ortho-phosphate) and chlorophyll-a concentrations at the four stations. In addition, diel sampling (2.5 hour sampling intervals over 25 hours) for nutrients and chlorophyll-a occurs at a minimum of one site each month. At least one weather station at each reserve records meteorological measurements of local temperature, wind speed and direction, relative humidity, barometric pressure, rainfall, and Photosynthetic Active Radiation at 15- to 30-minute intervals. Reserve staff have laid the technical groundwork necessary for the phase-one SWMP data collection network to be integrated into the backbone of the United States' Integrated Ocean Observing System (IOOS), with a near-real-time telemetry system for timely dissemination (NOAA 2004).

Photo Credit: Rookery Bay National Estuarine Research Reserve

Conservative estimates for the volume of data collected by the NERRS abiotic sampling program are: 13.5 million data points for water quality, 34.4 million data points for meteorological monitoring, and 31,104 data points for nutrient monitoring.



Wetland change analysis within the Elkhorn Slough, CA NERR utilizing habitat mapping techniques to quantify a 50% loss in marsh vegetation in the past 150 years (Van Dyke and Wasson 2005).

Phase 2 of SWMP focuses on characterizing biotic diversity in reserve estuarine ecosystems by assessing community composition and species abundance and distributions. Reserve projects will explore patterns of inter-annual variability and spatial distribution of estuarine communities, including emergent and submerged vegetation, invasive species, benthic, plankton and nekton communities, as well as targeted monitoring for the occurrence and distribution of invasive species. Since 2004, biomonitoring demonstration projects at 16 reserves have focused on developing baseline information on submerged and emergent vegetation distribution for use in future land use change research, determining changes in the health and distribution of these communities with long-term changes in water quality and quantity, and quantifying changes in estuarine habitat types. Rigorous protocols were established to ensure a national strategy for implementing this biomonitoring initiative, while retaining local flexibility as appropriate for individual reserves (Moore and Bulthius 2003). There are currently plans for a special journal edition focusing on local, regional, and national application of this biological monitoring information.

Phase 3 of SWMP is well-aligned with phase 2, as both of these efforts utilize remote sensing imagery and ground truthing. The central objective focuses on tracking and evaluating changes over time in coastal and estuarine

habitat and land use in the watershed. Reserve staff have developed a common classification system to provide the system with consistent, and thus nationally comparable, habitat and watershed mapping efforts (Kutcher et. al. 2005). The use of a common classification system will enable the NERRS to assess habitat change at local, regional, and national scales and identify the status of coastal habitats (i.e., degrading, improving, or maintaining). In addition, system-wide use of this classification system will provide a baseline of information that can be applied to management and restoration activities and guide conservation and protection of these important habitats. Currently, five reserves have piloted this classification system and the protocol was refined in the fall of 2005. It is anticipated that this classification system will be adopted by the reserves in 2006. Phases 2 and 3 will be implemented as resources become available.

Further details regarding parameters measured, data acquisition, data dissemination, deployment protocols, developing phases of SWMP, and applications of NERRS SWMP data within research, coastal decision making and education communities are available in the NERRS SWMP Plan (NOAA, 2002; Appendix A) and the NERRS SWMP 10th Anniversary Report (Owen and White, 2005). To ensure the collection of accurate, high quality SWMP data, the reserve system established a Centralized Data Management Office (CDMO; http://cdmo.baruch.sc.edu) in 1995. Quality assurance/quality control protocols have been established for the collection of all monitoring parameters and for the metadata (FGDC content compliant) associated with the time-series datasets.

A number of publications use and synthesize SWMP data. A recent special issue of the Journal of Coastal Research highlights a number of reserve research efforts (Kennish and Finkle 2004), and past syntheses have produced additional information regarding patterns within the reserve system (Wenner et. al., 1998 and 2000).

NERRS Graduate Research Fellowships

The NERRS Graduate Research Fellowship (GRF) program provides master's degree students and Ph.D. candidates with an opportunity to conduct research of local and national significance focusing on enhancing coastal zone management. Since its inception in 1997, the program has funded more than 160 fellows from 56 universities across the country. The five research focus areas for the GRF program are: eutrophication, effects of non-point source pollution and/or nutrient dynamics; habitat conservation and/or restoration; biodiversity and/or the effects of invasive species; mechanisms for sustaining resources within estuarine ecosystems; and economic, sociological, and/or anthropological research applicable to estuarine ecosystem management (Figure 1).

Reserve Site-Specific Research

The National Estuarine Research Reserves serve as living laboratories for on-site staff, visiting scientists and graduate students. Since its inception, a primary goal of the program has been to ensure a stable environment for research through long-term protection of reserve resources and ecosystems. Reserve management plans include site-based research

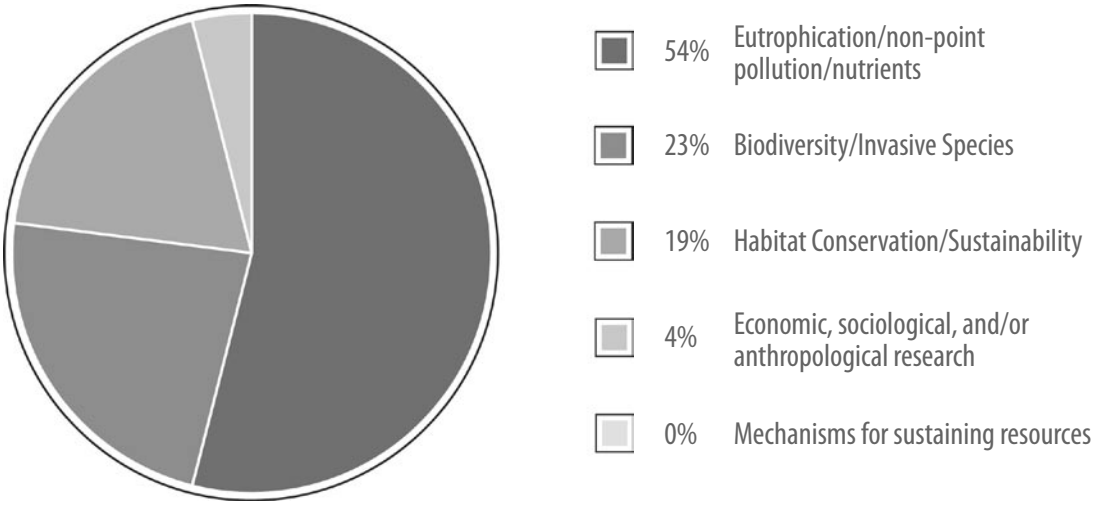


Figure 1. *Snapshot of NERR Graduate Research Fellowship research project focus areas for 2005.*

and monitoring priorities. Research activities within the reserve system occur in a number of ways. Each reserve has a research coordinator who is primarily responsible for coordinating research and monitoring efforts that occur within the reserve. As a group, the research coordinators' scientific expertise encompasses a wide range of subjects including nutrient biogeochemistry, population, community and ecosystem ecology, and physical oceanography. The breadth of knowledge and expertise that is shared among research coordinators constantly improves and pushes the reserve system toward new and successful research opportunities focused on improving coastal management decisions at individual reserves and nationally. In addition, scientists from a variety of backgrounds (e.g. academic, non-governmental, state and federal governments) conduct research within each reserve in coordination with reserve research staff. This also broadens the scientific knowledge base for the NERRS.

Research and Monitoring Partnerships

Additional research and monitoring efforts within the reserves are supported by a series of partnerships within NOAA and other programs. Examples of these partnerships include:

- The Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) is supported through a partnership between NOAA and the University of New Hampshire (http://www.ciceet.unh.edu). Research projects funded by CICEET occur within reserve boundaries or the adjacent watershed and focus on a variety of environmental issues from habitat restoration research to developing and piloting new technologies to monitor water quality and contaminants.

- NOAA's Chesapeake Bay Office (NCBO) and the NERRS support specific research and monitoring programs that focus on understanding and restoring Chesapeake Bay communities.

- NOAA's Coastal Services Center (CSC) has supported remote sensing and geographical information system (GIS) tools, training, and development programs within the reserve system.

- NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) has partnered with reserve sites to demonstrate the effectiveness of collaboration to produce an improved, more effective product that will be used by coastal managers and others for improved decision making. CO-OPS National Water Level Observation Network (NWLON) is expanding to include reserve sites in an effort to link SWMP data with more detailed tide, water level, and weather information within the Reserve.

- NOAA's National Weather Service (NWS) and National Environmental Satellite, Information, and Data Service (NESDIS) have partnered with the NERRS to deliver newly telemetered, real-time, SWMP weather and water data through NOAA's Geostationary Operational Environmental Satellites (GOES) and the NWS's Hydrometerological Automated Data System (HADS) to the NERRS Centralized Data Management Office.

- NOAA's Sea Grant Programs, Coastal Zone Management Programs, and National Marine Sanctuary Programs support research projects that address priority research needs within or adjacent to reserve sites.

- The National Atmospheric Deposition Program (NADP)/National Trends Network (NTN) and United States Geological Survey (USGS) have established atmospheric deposition monitoring programs within and close to reserve boundaries.

- The Environmental Protection Agency's National Estuary Program (NEP) and the NERRS collaborate at local scales to accomplish research that is relevant for both programs and at national scales to improve science information exchange bewteen programs.

- The Smithsonian's Environmental Research Center (SERC) and the NERRS have ongoing collaborations that focus on monitoring and forecasting expansion and distribution of invasive species within the reserve system.

- NOAA's National Centers for Coastal Ocean Science (NCCOS) collaborates with the reserve system to investigate long-term trends in eutrophication and contaminants in estuarine systems across the nation. The reserves continue to be involved in NCCOS's national estuarine eutrophication assessments and the Mussel Watch Program.

- NOAA's Educational Partnership Program (EPP) established the Environmental Cooperative Science Center (ECSC) in October 2000 with Florida A&M University in collaboration with Delaware State University, Jackson State University, Morgan State University, South Caro-

lina State University, and the University of Miami Rosenstiel School. The ECSC addresses ecological and management issues through studies and collaboration with several NERR sites and the Florida Keys National Marine Sanctuary. The ECSC NERR partners include: Apalachicola, FL NERR; Grand Bay, MS NERR; ACE Basin, SC NERR; Delaware NERR; and Chesapeake Bay, MD NERR.

- The National Science Foundation's coastal Long-term Ecological Research (LTER) sites offer the NERRS additional research and collaborative opportunities. Sapelo Island NERR is located within the Georgia Coastal Ecosystems LTER site.

Research Plan Framework and Development

The research plan for the NERRS has been developed to address topic areas and technological needs identified at national, regional, and local levels. Considerable challenges must be overcome to develop a coherent national research plan for the reserve system that can simultaneously incorporate and accommodate the flexibility in approaches and design that are necessary to meet local and regional coastal research and management needs, while also addressing nationally significant coastal issues. Scaling research priorities up from a local and regional perspective to address nationally relevant coastal issues requires the reserves to constantly evaluate how individual reserve research can support broader national estuarine information and application needs.

Development of this plan has been coordinated by NOAA's Estuarine Reserves Division with primary input from the individual reserves and NOAA's Office of Coastal Resource Management. Reserve research coordinators and managers contributed directly to the formulation of this plan by identifying the primary research needs and coastal management issues within reserve sites (Appendix B). The plan incorporates information contained in several documents produced by the reserve system including the NERRS Strategic Plan for 2005-2010 (Appendix C), the NERR System-Wide Monitoring Plan, NERR management plans, site profile documents (Appendix D), and local needs assessments conducted by the NERR Coastal Training Programs. Additional research needs and coastal management issues were identified through the findings of several recent compilations including: (a) the CICEET survey of coastal management needs for new and improved technology (2004); (b) the Coastal States Organization (CSO) census of national and regional priorities to improve links between science and coastal management needs (2004); (c) the CSO survey of state coastal observational and monitoring needs (2004); (d) research needs for coastal resource management identified by the Estuarine Research Federation (ERF, 2005); (e) the National Research Council priorities for coastal ecosystem science (1994); (f) the PEW Ocean Commission Report; and (g) findings from the U.S. Commission on Ocean Policy (2004). As an example of the range of coastal management priorities identified, Table 1 presents CSO's results for both national research needs and needs identified by NERRS Manager's as well as key estuarine threats identified by the PEW Ocean Commission. Information provided by these sources has been used to identify a series of reserve research priorities that are both nationally relevant and tailored to meet the regional and site specific needs of individual reserve sites.

Table 1. *Coastal management research needs and threats identified from surveys conducted by the Coastal States Organization and PEW Ocean Commission.*

The Coastal States Organization top ranked research needs:

Top National Level Research Needs	Top NERR Research Priorities
Cumulative Effects	Cumulative impact assessment
Source identification and tracking	Ecosystem indicators
Trends/change analysis	Source identification and tracking
Remote Sensing	Improved models
Improved Models	Rapid detection and monitoring of invasive species
	Risk and vulnerability assessments
	Restoration prioritization
	Ecological characterizations

The PEW Ocean Commission identified the following key estuarine threats and pressures:

Coastal development
Nutrient runoff into coastal rivers and bays
Unsustainable fishing activities impacting nearshore/estuarine systems
Invasive species introductions
Global climate change impacts

The framework for the NERR Research Plan provides a pathway for integration and support of site-based research projects to meet local, regional, and national coastal and estuarine management needs (Figure 2). Science investigations and research projects undertaken at individual NERR sites are supported by state, NOAA, and other sources, and are typically conducted by NERR scientists, graduate students, visiting investigators, contractors, and volunteers to meet the needs identified by local and regional coastal resource managers. Taken collectively, the research effort undertaken within the network of NERR sites contributes in a "bottom-up" manner to the goals and objectives of the NERR Research Plan. Conversely, the NERR Research Plan serves a "top-down" role to provide guidance, coordination, and the national context to support site-based research within the NERRS network. Financial support for the site-based research activities is typically derived from the states, federal agencies, regional programs, non-governmental organizations, and/or other sources depending on the topic and focus of the research problem. As the focal point for coordination of NERRS science activities, the NERR Research Plan serves as an integral element of the NERR Strategic Plan for 2005-2010. The NERR Strategic Plan functions to coordinate the research and monitoring

activities with other elements of the NERRS (e.g., education/outreach, coastal training, resource stewardship, and management). This in turn serves to facilitate investigations undertaken by multiple reserves, and to leverage support for NERRS research internally in cooperation with other NOAA science programs and externally in partnership with outside groups. Science activities completed under the guidance of the NERR Strategic Plan and NERR Research Plan contribute to the objectives of the NOAA-wide Research Plan (2005), and they address the cross-cutting issues identified by the Ecosystem Goal for Coastal and Marine Resources. Collective integration of NERRS science at many levels (e.g., NERRS sites, NERR Research Plan, NERR Strategic Plan, NOAA Research Plan) will help meet a sub-set of the national priorities for coastal and estuarine ecosystem science.

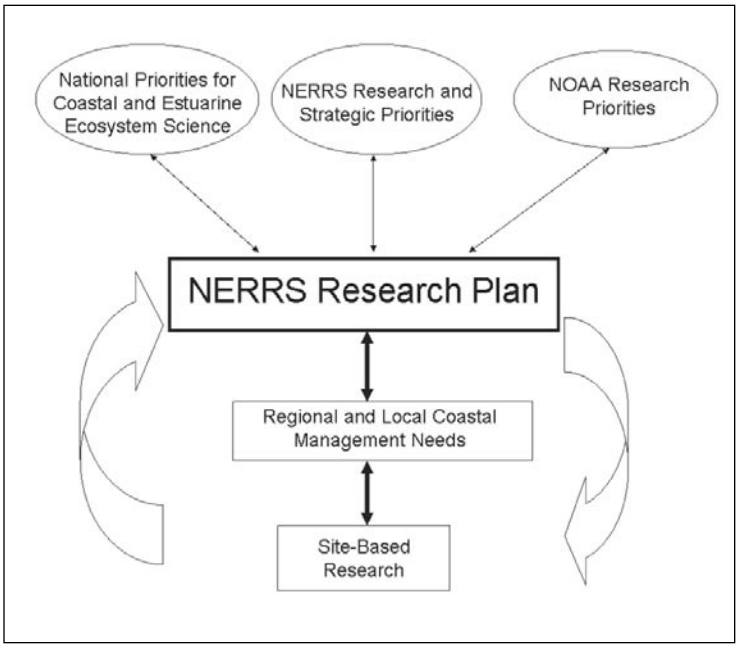


Figure 2. *The development components and anticipated science contributions associated with the NERRS Research and Monitoring Plan at local, regional, and national scales.*

Priority Coastal Management and Research Issues

The U.S. Commission on Ocean Policy recommended that NOAA adopt an ecosystem-based approach to the development of coastal and ocean policy that is based on the best available science for marine and estuarine ecosystems. NOAA's focus on protecting, restoring, and managing the use of coastal and ocean resources through an ecosystem approach is closely aligned with the specific research activities undertaken within the reserve system. The NERR Research Plan nests within the broader, NOAA 5-Year Research Plan, while simultaneously addressing the regional and local needs of the reserves.

The highest priority U.S. coastal management issues identified at both the national and regional levels focus on assessments of impacts due to changing shoreline and watershed land use and coastal habitat change (Table 1). It is clear that nationally and regionally, coastal managers are concerned about increased development pressures in coastal and estuarine areas, and are supportive of research and monitoring efforts that will address the growing need for information to document impacts on the coastal environment. Environmental contamination, habitat

degradation, eutrophication, invasive species, declines in fish species, freshwater diversions, sea level changes, and sediment problems are significant stressors to coastal and estuarine ecosystems. Consequently, it is not surprising that the top-ranked research needs for coastal managers are: (a) new approaches to address the cumulative effects of multiple environmental stressors, and (b) source identification and tracking for coastal environmental pollutants. Priority information needs identified by the U.S. coastal management community include quantitative data to describe temporal trends and changes in land use, coastal habitats, and habitat quality, and the priority needs for new technology focus on development of useful products from remote sensing imagery and improved conceptual and numerical models to predict the consequences of stressors on environmental change.

The priority research needs identified by the estuarine research community (e.g., academia, agencies, NGOs, and private-sector scientists; ERF, 2005) are highly complementary to those identified by the U.S. coastal management community. The highest priority research needs are: (a) investigations of anthropogenic impacts on estuarine ecosystem functions; (b) documentation of linkages among coastal land use activities and estuarine habitats; (c) increased understanding of environmental variability, sensitivity, and resilience; and (d) new infrastructure to link estuarine science, management, and policy (ERF, 2005). These priority estuarine research issues are consistent with the priorities for coastal ecosystem science identified by the National Research Council (i.e., integrated monitoring of coastal habitats; watershed hydrology and ecosystem processes; water quality and aquatic ecosystem functions; ecological restoration and rehabilitation; development of observational and predictive systems). In combination, the priority research needs identified by the U.S. coastal management and research communities clearly articulate a suite of pressing science-management issues that can be addressed by the network of representative reserve sites and the NERRS Research Plan. For example, within individual reserves, program priorities are broadly focused on research regarding habitat change/land use, cumulative impact assessments, tracking of pollutants, development of indicators that link land use with ecosystem impacts, estuarine ecosystem functions, invasive species, land use change analysis, the success of restoration efforts, habitat use by fish and shellfish, integrated monitoring, and improved models that predict and/or simulate changing environmental conditions.

National Estuarine Research Reserve System Research Plan

The NERRS Strategic Plan outlines four priority coastal management issues; land use and population growth, habitat loss and alteration, water quality degradation, and changes in biological communities. The five main NERRS research priority areas clearly address these identified estuarine threats and the supporting research questions, goals and strategies described below will enable the NERRS to better understand estuarine processes, provide scientific data that can be applied and thus improve coastal management decisions and the protection of estuarine habitats (Figure 3).

The five main NERR research priority areas were identified as a result of information complied from within the NERRS, NOAA and external sources as outlined previously. NERR research priority areas include:

- Habitat and Ecosystem Coastal Processes
- Anthropogenic Influences on Estuaries
- Habitat Conservation and Restoration
- Species Management
- Social Science and Economics

Research projects that are designed to tackle NERRS research priority areas will clearly address the four priority coastal management issues identified within the NERRS Strategic Plan and thus support improved coastal decision making and a greater understanding of estuarine systems. The research categories are interrelated on one or more levels. In addition, research can include natural or social science research. For example, social science and economic research can be used as a tool to address natural science issues. In the true ecological sense, this is a web of research topics with threads leading from topic to topic. NERRS- specific research questions are focused on coastal management issues related to these five priority areas.

Key Questions for each priority area might include:

Habitat and Ecosystem Coastal Processes

- What are the natural scales of variability in coastal and estuarine ecosystem processes?
- How do short-term climatic events (e.g., tropical storms and hurricanes), and large-scale events (e.g., El Nino, North Atlantic Oscillation, global climate change) impact estuarine water quality parameters and estuarine habitats?
- How do variable watershed inputs and oceanic physical forcing drive changes in estuarine ecosystems (including nutrient cycling, sediment transport, larval transport, etc.)?

Anthropogenic Influences on Estuaries

- How do human activities impact estuarine water quality, living resources (e.g.,

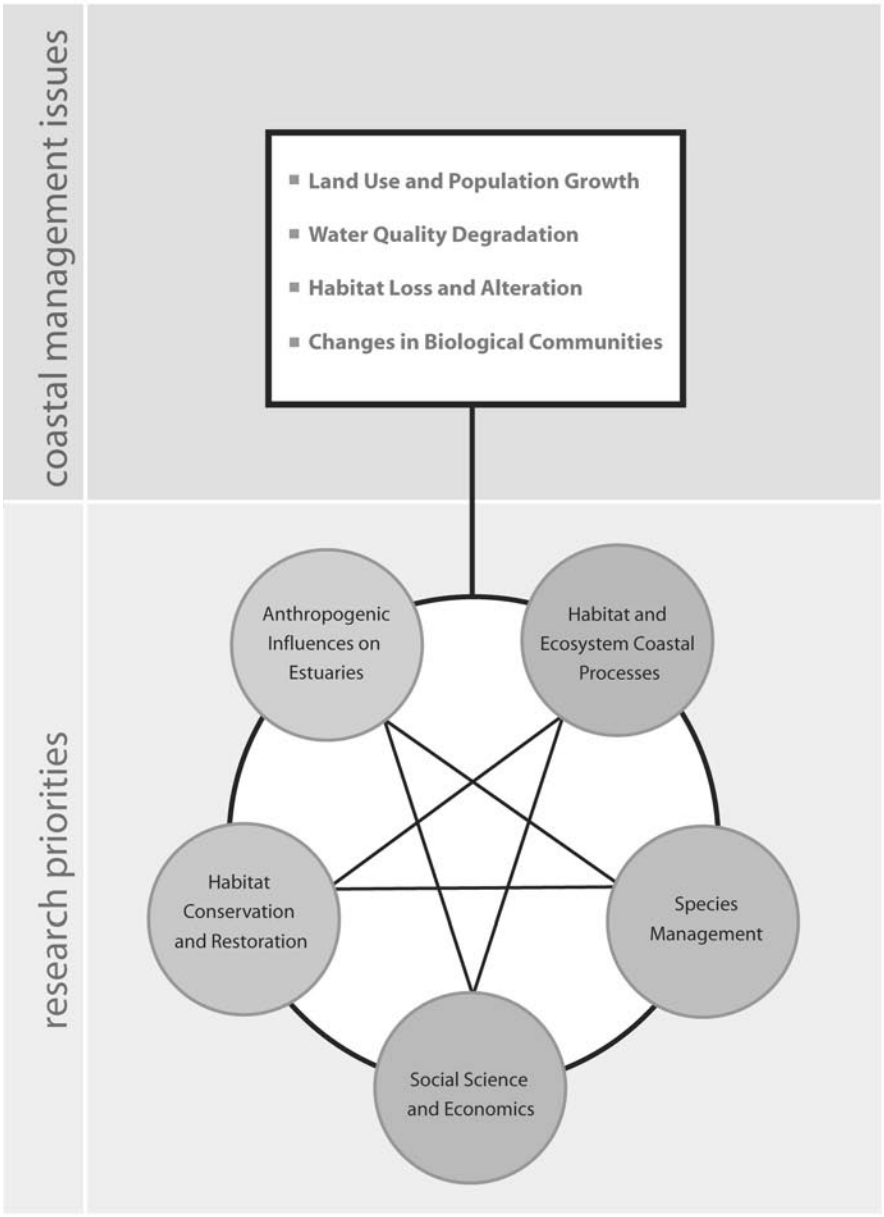


Figure 3. *The 5 NERRS Research Priorities, anthropogenic influences on estuaries, habitat and ecosystem coastal processes, habitat conservation and restoration, species management and social science and economics address key coastal management issues.*

submerged aquatic vegetation, benthic communities, habitat fragmentation), and ecosystem function (or "services")?

- Are current watershed and coastal nutrient management measures effective in minimizing impact to estuarine ecosystems and resources?
- What is the magnitude and impact of atmospheric deposition on estuaries?

Habitat Conservation and Restoration

- What impacts does climate change have on habitat integrity and restoration success?
- How does the restoration of tidal hydrology impact estuarine communities (e.g. colonization of invasive species, resiliency of native species, etc.).
- What are the linkages between adjacent upland habitats and tidal wetlands and how critical are those links to the recovery of wetland function?
- What invasive species control methods are effective?
- How can reserves serve as reference sites for restoration efforts?

Species Management

- How do invasive species affect native species and communities?
- What tools can be developed and used to detect invasive species, respond rapidly and appropriately to these events, and monitor for additional impacts?
- Can natural variations in the distribution and density of organisms be distinguished from human impacts on these populations?
- How do estuarine and coastal communities and individual species populations change under varying environmental conditions?
- How are estuarine species and communities affected by landscape or watershed scale changes (e.g., habitat proximity, subtidal-intertidal linkages, connectivity)?

Social Science and Economics

- How are coastal populations demographics changing and how does this/will this impact natural resource protection and management?
- What are the economic tradeoffs/effects of increasing development and urbanization in the coastal zone on traditional commercial enterprises such as seafood harvesting, etc.?
- How do human perceptions of health risks influence coastal decision making and natural resource protection?
- What are the cumulative impacts of multiple human recreational and economic activities on the coastal environment?

Implementation Strategy

Research Goals

The reserve research and monitoring plan includes a number of priority goals for the system (a few of which are outlined below) to support national and regional efforts toward improving the protection of coastal and estuarine natural resources by conducting research that supports sound coastal decision making. These goals are not meant to be an exhaustive list as by definition this research plan is designed to be supportive of regional and local research initiatives that address reserve system and NOAA research needs. The goals listed below provide a basic foundation on which reserve science efforts can build. It is fully anticipated that these strategies will be modified appropriately over time as the Reserve system continually assesses the quality and impact of research results and products in order to continue to improve and sustain coastal environments (Appendix E). The desired ecosystem approach to management is an iterative process, where results from previous actions and research are used to refine and improve future efforts in research and management decisions. Implementation of some strategies depends on the availability of sufficient resources.

Research Goal 1: Biological, chemical, physical, and ecological conditions of reserves are characterized and monitored to describe reference conditions and to quantify change.

Objectives:

1. Water and weather parameters, biodiversity, and habitats located within the reserve and nearby watershed areas are sufficiently characterized, both spatially and temporally, to support trend analysis efforts.

2. Biological monitoring data collected by the reserve system are incorporated into an accessible database for use.

3. Biological monitoring efforts within the NERRS are synthesized regularly as appropriate at national, regional and local scales.

Strategies:

- Complete site profiles.

- Continue system-wide measurements of the short-term variability and long-term changes in estuarine water quality and meteorological parameters, consider expanding suite of standard water quality parameters tracked (e.g. addition of chlorophyll a to fixed station sampling) as possible.

- Collect system-wide measurements of the short-term variability and long-term changes in submerged aquatic vegetation and emergent vegetation.

- Collect additional appropriate biological monitoring information on important

habitats, species, and ecological functioning within reserves.

- Link system-wide measurements of chemical and physical parameters with biological monitoring information.
- Implement a system-wide habitat classification system that allows for site specific and system-wide analysis.
- Synthesize biological monitoring pilot project data and revise protocol to reflect lessons learned and move toward system-wide operational status.
- Develop a system-wide remote-sensing strategy that supports and enhances ongoing biological monitoring and habitat classification efforts.
- Partner with appropriate university, state agency, federal agency, local government and private entities to bring monitoring of sediment quality, benthic communities, nekton populations and shoreline change into reserves.
- Integrate NERRS monitoring data into the national IOOS program.

Research Goal 2: Scientists conduct estuarine research at reserves that is relevant to coastal management needs and increases basic understanding of estuarine processes.

Objectives:

1. Research efforts focus on understanding the response of estuarine and coastal processes to specific natural and anthropogenic impacts.
2. Research efforts focus on estuarine habitat and species management and the restoration of critical ecosystem function.
3. Research efforts incorporate an ecosystem-based approach to management that involves multiple stakeholders.
4. Scientists from multiple agencies (ie. academic, governmental, NGO's, etc.) utilize reserves as a platform for research.

Strategies:

- Attract CICEET, GRF, and external researchers to reserves to work on priority research topics: habitat and ecosystem coastal processes, anthropogenic influences on estuaries, habitat conservation and restoration, species management, and social science and economics.
- Revisit GRF priority research areas to update them as appropriate to reflect NERRS coastal management needs.
- Utilize SWMP data to drive hypothesis driven research within reserves and adjoining watersheds.

- Support ecosystem-based approaches to coastal research and management projects that incorporate adaptive management strategies to improve research efforts and applications.

- Design and regularly update a database that archives and tracks research projects within the NERRS that are supported by non-Section 315 NERRS funding (i.e. other NOAA monies, academic, NGO, external funding sources, etc.) and address priority coastal management and estuarine research needs.

- Improve current partnerships and explore new opportunities to leverage resources that support reserve priority research efforts.

- Facilitate research efforts between and across NERRS, both regionally and nationally, to address important coastal issues.

- Design a regional or national assessment of the NERRS that integrate research results from the reserves to determine if NERRS environmental conditions are improving or declining and why (i.e. a "report card" for the NERRS).

Research Goal 3: Scientists, educators, and coastal managers have access to NERRS datasets, science products and results.

Objectives:

1. Scientists are aware of available NERRS datasets and research products.

2. Biological monitoring data is available for academic scientists, coastal managers, and educators to use.

3. Data visualization products are available.

Strategies:

- Develop a useful and informative database for accessing past and current research projects, data, and resulting publications and products.

- Establish a data management strategy and database to support biological monitoring and land use/habitat information.

- Disseminate science through publications, outreach and technology transfer.

- Develop and implement appropriate communication tools to increase awareness of science conducted, data application, and data availability within the NERRS.

- Assess CDMO capabilities and needs in relation to expanding NERRS research and monitoring, data accessibility, and data visualization efforts.

Research Goal 4: The scientific, coastal management and education communities, as well as the general public, use data, products, tools, and techniques generated at the NERRS.

Objectives:

1. Researchers and coastal managers identify priority resource needs that will improve research activities at the local, regional, and national scales.

2. Enhance the use of NERRS scientific data in coastal training, stewardship, and education programs within the NERRS.

3. The NERRS are increasingly recognized as a primary source of information about estuaries and coastal areas.

Strategies:

- Re-evaluate priority research needs biennially.
- Revise and update SWMP Plan based on NERRS research and monitoring needs.
- Conduct a SWMP External Review.
- Coordinate with education and outreach professionals early in the formation of research activities, where feasible, to target educational product development and dissemination from research activities.
- Provide science based information and training to individuals and organizations that make decisions about coastal resources on a regular basis in a professional or volunteer capacity.
- Improve the ability of restoration practitioners to restore and protect coastal ecosystems.
- Provide science based information to assist in the production and dissemination of educational materials and web based products that use science generated at the reserve.
- Provide science based information and training to citizens so that they can make informed decisions about protecting coastal resources through their own actions.

Appendices:

A. NERRS SWMP Plan Executive Summary

B. Regional NERRS research priority issues

C. NERRS Strategic Plan (2005-2010)

D. NERRS Site Profile Status

E. Key milestones anticipated for achieving NERRS research goals

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Appendices

Appendix A: NERRS System wide Monitoring Program Plan Executive Summary

THE NATIONAL ESTUARINE RESEARCH RESERVE'S SYSTEM-WIDE MONITORING PROGRAM (SWMP): A SCIENTIFIC FRAMEWORK AND PLAN FOR DETECTION OF SHORT-TERM VARIABILITY AND LONG-TERM CHANGE IN ESTUARIES AND COASTAL HABITATS OF THE UNITED STATES

(Updated Spring 2006)

Executive Summary

Estuaries are among the most dynamic and productive environments known. They are transitional places where salt and fresh water mix and serve as nursery areas for numerous commercial fish and shellfish species. These habitats also act as rest stops for migratory birds, filters for pollution and buffers against coastal erosion. The high value that society places on estuaries for living, working and recreation has made these habitats among the most densely populated in the United States.

An increased awareness of estuarine degradation resulted in the passage of legislation aimed at protecting estuarine ecosystems. A landmark piece of legislation enacted by Congress was the Coastal Zone Management Act (CZMA) of 1972, which was the beginning of what became the National Estuarine Research Reserve System (NERRS). Currently, 27 reserves in 22 states and territories protect over 1.3 million acres of estuarine waters, wetlands and uplands. The NERRS was built on a foundation of partnerships among state and federal agencies and community groups. The reserves have a management framework in place that links stewardship, public education and scientific research and thus provide an ideal vehicle to establish a nationally coordinated monitoring program.

In 1992, the reserve system proposed the establishment of a coordinated monitoring program that would attempt to identify and track short term variability and long term changes in the integrity and biodiversity of representative estuarine ecosystems and coastal watersheds for the purposes of contributing to effective coastal management. The initial phase of the NERR System wide Monitoring Program, known by its acronym SWMP (pronounced "swamp"), began in 1995. The initial focus was on monitoring a suite of water quality and atmospheric variables over a range of spatial and temporal scales. Water quality parameters measured include pH, salinity, conductivity, temperature, dissolved oxygen, turbidity and nitrate,

ammonia, ortho-phosphate, and chlorophyll a. Atmospheric parameters measured include temperature, wind speed and direction, relative humidity, barometric pressure, rainfall, and photosynthetic active radiation.

The purpose of the updated SWMP document is to lay out a revised scientific framework and plan for the NERR SWMP that will assist in guiding the program with the perspective gained over the past 10 years, for the next 10 years. It is not a static document, especially regarding costs and implementation details, but it portrays priority activities for ongoing and future SWMP efforts. This document describes a conceptual framework for NERR SWMP laying out the steps that will assist in addressing coastal management problems. Updates, including steps taken to expand abiotic monitoring within the reserves and initiate the second and third phases (e.g. biological monitoring and watershed and land use classifications) are included. In addition, the SWMP plan contains some general areas for future targeted monitoring including additional expansions of abiotic, biological and watershed/land use components (e.g., contaminant monitoring, monitoring of invasive species, conducting benthic/subtidal mapping, etc.).

The advantages of the NERRS monitoring program are that it:

- Provides an ecosystem-based network for understanding the temporal and spatial variability of ecosystem components and their interactions.
- Provides a long-term database for the estuarine reserves' protected area network.
- Establishes a baseline for measuring changes in environmental conditions and ecological processes.
- Provides a research framework for evaluating ecosystem conditions and interpreting and predicting responses to change.
- Provides the basis for an ecosystem-based approach to managing coastal resources.

The scientific value of NERR SWMP data increases over time because it is through the collection of long-term data that subtle changes in environmental conditions are identified. This established monitoring program continues to be an opportunity to increase our understanding of how various environmental factors influence estuarine processes by collecting high-quality, long-term data.

By understanding how estuaries function and change over time, we can begin to predict how these systems respond to changes in climate and human-induced perturbations. Research is critical to the interpretation of monitoring results and for testing hypotheses generated by monitoring. Whereas monitoring determines whether and how

much the environment has changed from its reference state, research helps establish causal relationships. The reserve system's monitoring program, coupled with NERR-supported research programs, provides a foundation for developing solutions to coastal management problems by answering how estuarine ecosystems change and why.

Appendix B. Regional NERRS Research Priority Issues

		REGIONS							
		NW Pacific	California	Caribbean	Northeast	Mid-Atlantic	Southeast Atlantic	Gulf of Mexico	Great Lakes
	Total Count (Rank Order)	Region Total (N = 3 sites)	Region Total (N = 3 sites)	Region Total (N = 1 site)	Region Total (N = 5 sites)	Region Total (N = 4 sites)	Region Total (N = 5 sites)	Region Total (N = 4 sites)	Region Total (N = 1 site)
Non-point source pollution	15	2	3	1	3	1	3	2	0
Hydrology	12	0	2	1	2	2	2	2	1
Nutrient studies	11	1	0	0	3	2	3	1	1
Restoration	11	1	3	1	2	1	2	1	0
Contaminants	10	1	1	0	2	1	3	1	1
Invasive Species	10	1	3	1	1	1	2	1	0
Sediment Transport / Processes	10	1	0	1	3	1	2	1	1
Physical Oceanography	9	2	0	1	2	1	2	1	0
Land Use (change/planning)	8	0	2	0	2	2	1	1	0
Other	8	0	0	0	3	2	0	3	0
Water Quality	7	1	3	0	2	0	1	0	0
Climate Change	6	0	0	0	3	1	1	0	1
Biodiversity	6	0	0	1	2	0	1	2	0
Energy Flow	4	0	0	0	1	1	1	0	1
Habitat Conservation	4	0	2	1	0	1	0	0	0
Plant/Animal Growth	4	2	0	0	1	1	0	0	0
Indicator Species	3	0	0	0	2	0	0	1	0
Cultural Resources	3	0	0	0	0	1	1	1	0
Human Impacts	3	0	0	0	1	1	0	1	0
Methodology Development	2	0	2	0	0	0	0	0	0
Plant/Animal Interactions	2	0	0	0	0	1	1	0	0
Management of Special Status Species	2	0	2	0	0	0	0	0	0
Storm Impacts	2	0	0	0	0	0	1	0	1
Sustaining Resources	2	0	0	1	0	0	1	0	0
Larval Transport	2	1	0	0	1	0	0	0	0
Community/Population Dynamics	1	0	0	0	1	0	0	0	0
Biological Oceanography	1	1	0	0	0	0	0	0	0

Appendix C: NERRS Strategic Plan (2005-2010)

vision

Healthy estuaries and coastal watersheds where coastal communities and ecosystems thrive.

mission

To practice and promote coastal and estuarine stewardship through innovative research and education, using a system of protected areas.

goals

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 peoples' ability and willingness to make informed decisions and take responsible actions that affect coastal communities and ecosystems.

Introduction

For thousands of years, coastal and estuarine environments have provided people with food, safe harbors, transportation access, flood control, and a place to play and relax. The pressures on the nation's coast are enormous and the impacts on economies and ecosystems are becoming increasingly evident. Severe storms, climate change, pollution, habitat alteration and rapid population growth threaten the ecological functions that have supported coastal communities throughout history. As a network of 26 (soon to be 27) protected areas established for long-term research, education and stewardship, the National Estuarine Research Reserve

System has a unique role to play in keeping coastal ecosystems healthy and productive.

The reserve system is a partnership program between the National Oceanic and Atmospheric Administration and coastal states that has protected more than one million acres of coastal and estuarine habitat since the program was established by the Coastal Zone Management Act in 1972. NOAA provides funding, national guidance and technical assistance. Each reserve is managed on a daily basis by a lead state agency, non-profit organization or university with input from local partners. Through careful stewardship, innovative science and education, and relevant training programs, the reserves encourage careful management and protection of local estuarine and coastal resources.

The Coastal Zone Management Act created the reserve system to protect estuarine areas, provide educational opportunities, promote and conduct estuarine research and monitoring, and transfer relevant information to coastal managers. For the next five years, core reserve programs will focus on four priority topics:

- Impacts of land use and population growth;
- Habitat loss and alteration;
- Water quality degradation;
- Changes in biological communities.

The National Estuarine Research Reserve System's 2005-2010 Strategic Plan articulates how the strengths of the reserve system will be applied to address the major challenges of coastal management.

Priority Coastal Management Issues:

1. Land Use and Population Growth

The United States' exploding coastal population results in competing demands for clean water, beaches, recreational and commercial space, infrastructure and housing. In 2003, an estimated 153 million people lived in coastal counties, which is approximately 53% of the total US population. Pressure to develop land in coastal areas is escalating at more than twice the rate of population growth. Land use changes can significantly impact coastal and estuarine species and habitat. The Pew Ocean Commission reports that when more than 10% of a watershed is covered in impervious surface such as roads, roofs and parking lots, aquatic resources begin to degrade.1

Coastal population and land use demands are not only increasing, they also are changing. Demographic and socio-economic trends show that the backgrounds and interests of people who are moving to the coast may be different from those of traditional fishing, commerce, or beach communities. The way people value and understand their relationship to the coast is reflected in the personal, political and professional choices they make. To make wise coastal resource management decisions, we need to understand the relationships among estuarine ecosystems and changing landscapes and attitudes. National Estuarine Research Reserves encourage the development and use of science based knowledge and tools in local land use planning, community development, and stewardship of public and private property.

2. Habitat Loss and Alteration

More than half of the nation's coastal wetlands have vanished since European settlement.2 Estuarine and coastal environments continue to be altered and eliminated due to dredging, dams, recreational and commercial uses, flood and hazard mitigation, residential and infrastructure development, commercial port activities, and agriculture. Many of these activities disturb the physical, biological and chemical attributes of the estuary and therefore degrade the plants and animals that depend on the habitat to survive. Seagrass beds, marshes, shellfish, bird and fish populations can be affected by sedimentation, erosion, and hydrological, chemical or physical alteration of the habitat. Estuarine ecosystems also are vulnerable to coastal storms and sensitive to changes in climate and sea level. Coastal managers want to know more about how their choices influence coastal habitat and the species that live there. Better information will ensure that alternatives are considered for permitting, as well as planning and implementing successful restoration and mitigation efforts.3

Reserve research and monitoring programs increase the fundamental understanding of estuarine dynamics and add new information about the causes and consequences of changes in habitat quantity and quality. Research and stewardship programs at the NERRs also develop, implement and evaluate new techniques to restore and protect estuarine resources. Training programs and advisory services make this information available to professionals. Through education programs conducted at the reserves, students and citizens learn why these habitats are important and what they can do to keep them healthy.

3. Water Quality Degradation

Improving the condition of coastal water quality is a goal of the Coastal Zone Management Act and an ongoing struggle for all coastal regulatory agencies. Despite continuing local, state and federal investments, more than 20,000 beach closures were enforced in 20044 and more than 60% of estuarine waters were classified by the EPA as having degraded water in 2005.5 Excess nutrients and chemical and biological contamination can cause human health problems and threaten aquatic life.

The Reserve System has been collecting water quality data for ten years to quantify short term variability and long term changes in estuarine waters. Through monitoring and studying changes in water quality, the reserves investigate how human activity, weather patterns, and estuarine characteristics contribute to changes in water quality that affect ecological processes and, consequently, human health. Reserves apply the knowledge generated through research and monitoring to improve water quality through habitat protection, restoration, and training and outreach programs.

4. Changes in Biological Communities

Biological communities are changing as a result of invasive species, over-harvest, climate changes, pollution, and habitat destruction. Invasive species out-compete or consume native organisms; habitat alteration and destruction displace some species and create opportunities for others; and changes in parameters such as temperature and salinity can shift the distribution of plants and animals. Chemical contamination and nutrient enrichment damage habitat and can alter the structure of floral

and faunal communities. Over-harvesting biological resources also can change community structure and threaten valuable species. These problems impact natural interactions and linkages and lead to cascading indirect effects throughout the ecosystems.

Reserve research, stewardship, education, and training programs focus on understanding how changes in biological communities affect the way estuaries function. To minimize the negative impact of these changes, reserves investigate and communicate how to balance public needs with the protection of increasingly susceptible natural resources.

A Local Approach to National Priorities

Land use and population growth, water quality degradation, habitat loss and alteration, and changes in biological communities are not the only topics that reserves work on, but these four have risen to the top as deserving of adequate and strategic investment for the national system. These four topics are high priority science and training needs for coastal managers.3 Reserve scientists, educators and land managers have identified these topics as locally and nationally important and appropriate to the mission of the National Estuarine Research Reserve System. Increased understanding about these topics will improve the reserve system's ability to protect and restore coastal watersheds and estuaries and empower individuals to make informed decisions. The nation's coasts and estuaries need to be managed, understood and appreciated at multiple scales. Through a network of locally oriented programs around the country, the reserve system provides insight into common information and management needs as well as data for use by local, regional and federal scientists and decision makers. Working at both the site level and as a national system, reserves have a greater impact than could be achieved through community efforts alone.

The goals, objectives and strategies outlined in this strategic plan will guide and support the National Estuarine Research Reserve System in its nation-wide efforts to improve coastal management, advance estuarine research, and educate current and future generations of coastal stewards.

Guiding Principles

- Strong partnerships between NOAA, state agencies and universities, and other local partners are critical to the success of the reserve system.
- The reserve system integrates science, education and stewardship on relevant topics to maximize the benefits to coastal management.
- Reserves serve as a catalyst and a focal point for demonstrating and facilitating objective problem solving and best management practices.
- Reserves engage local communities and citizens to improve stewardship of coastal areas.
- Reserves implement an ecosystem-based management approach.

Goal One:

Strengthen the protection and management of representative estuarine ecosystems to advance estuarine conservation, research and education.

Objectives:

1. Biogeographically and typologically representative estuarine ecosystems are protected through the designation of new reserves.

2. Biological, chemical, physical, and community conditions of reserves are characterized and monitored to describe reference conditions and to quantify change.

3. Reserve ecosystems are conserved through land acquisition, natural resource management and restoration.

Strategies:

- Identify and designate new reserves consistent with system-wide policy and available resources.

- Collect system-wide measurements of the short-term variability and long-term changes in the water quality, biotic communities and diversity, land-use and land cover characteristics of estuarine ecosystems to support effective coastal zone management.

- Collect baseline information about the biological, physical, chemical, and socioeconomic parameters of reserve biological and human communities.

- Integrate NERRS monitoring, data management, education and training capabilities in regional ocean observing systems.

- Implement land acquisition plans to enhance the long term integrity and diversity of reserve habitats.

- Restore and actively manage reserves' natural resources to meet local habitat and human use goals.

- Work collaboratively with other programs to evaluate and apply advanced technologies and tools to support effective coastal management.

- Provide facilities and support to manage the natural resources within reserve boundaries.

Goal Two:

Increase the use of reserve science and sites to address priority coastal management issues.

Objectives:

1. Scientists conduct estuarine research at reserves that is relevant to coastal management needs.
2. Scientists have access to NERRS datasets, science products and results.
3. The scientific community uses data, tools and techniques generated at the NERRS.

Strategies:

- Understand coastal decision maker science and training needs through needs assessments, coastal management science needs surveys, etc.
- Work collaboratively with other programs to conduct research on priority management issues in the reserves.
- Offer Graduate Research Fellowships to master's and doctoral students to conduct science that is relevant to coastal management and to train students in estuarine science.
- Deliver monitoring and observation data to the scientific community.
- Disseminate reserve science through publications, outreach and technology transfer.
- Generate time-series data and empirical studies to describe the ecological condition of reserve habitats.
- Promote reserve science products through web sites, communication materials, and other avenues to meet the needs of diverse stakeholders.
- Increase visibility and reinforce the credibility of NERRS science through communication efforts about NERRS research and monitoring.
- Attract scientists and practitioners to use reserves as reference sites.
- Conduct and facilitate relevant research in reserve watersheds.
- Synthesize reserve data into information for use in decision making.
- Conduct and facilitate research into education effectiveness and behavior change.
- Ensure that reserves have facilities and research support to meet the needs of visiting scientists and staff.

Scientist: *A person who uses principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.*

Goal Three:

Enhance people's ability and willingness to make informed decisions and take responsible actions that affect coastal communities and ecosystems.

Objectives:

1. People are aware of the ecological, economic, historical, and cultural importance of estuarine resources.

2. People understand how human choices and natural disturbances impact social, economic, and estuarine ecological systems.

3. People apply science-based information when making decisions that could impact coastal and estuarine resources.

Strategies:

- Provide educational opportunities that increase students' understanding of estuarine science and technology.

- Implement and participate in public programs and events to raise awareness and understanding about estuaries and the NERRS.

- Produce and distribute educational materials and web-based products that raise public awareness about estuaries, the NERRS, and NERRS education products.

- Train teachers to educate students about coastal watersheds and estuaries.

- Deliver monitoring and observing data to diverse user groups in a useful format.

- Improve the willingness and ability of communities to restore and protect coastal ecosystems.

- Provide science-based information and training to individuals and organizations.

- Assist restoration practitioners in developing and applying effective restoration techniques.

- Implement volunteer programs to engage local citizens in advancing the goals of the reserves.

- Conduct programs to encourage people to make personal choices that reduce their impact on coastal resources.

- Evaluate programs to determine how people apply information and knowledge.

- Build and maintain educational facilities and interpretive displays.

Appendix D. NERRS Site Profile Status

Sites completed profile

	Year published
ACE Basin, SC	**2001**
Delaware	**1999**
Elkhorn Slough, CA	**2002**
Great Bay, NH	**1992**
Jobos Bay, PR	**2002**
Kachemak Bay, AK	**2003**
Old Woman Creek, OH	**2004**
Rookery Bay, FL	**2003**
Sapelo Island, GA	**1997**
Tijuana River, CA	**1992**
Waquoit Bay, MA	**1996**
Weeks Bay, AL	**1996**
Hudson River, NY	**2006**

Sites planning profile

	Anticipated publication year
Apalachicola Bay, FL	2006
Chesapeake Bay, MD	2008
Chesapeake Bay, VA	2007
Grand Bay, MS	2006
Guana-Tolomato-Matanzas, FL	2006
Jacques Cousteau, NJ	2007
Narragansett Bay, RI	2007
North Carolina	2006
North Inlet-Winyah Bay, SC	2006
Padilla Bay, OR	2007
San Francisco Bay, CA	2007
South Slough, OR	2006
Texas-Mission Aransas	2009
Wells, MA	2006

Appendix E. Key milestones anticipated for achieving NERRS research goals

Research Goal	Milestones*	Products*	Y1	Y2	Y3	Y4	Y5
1. Biological, chemical, physical, and ecological conditions of reserves are characterized and monitored to describe reference conditions and to quantify change.	Site Profiles completed	3 site profiles/year	x	x	x	x	x
	Revise SAV/Emergent Biomonitoring protocol	Updated protocol	x				
	Summarize initial SAV/Emergent Biomonitoring projects	Synthesis document	x	x			
	Implement NERRS Habitat Classification System	At least 3 sites employ/year	x	x	x	x	x
	Develop a NERRS Remote Sensing Strategy	NERRS remote sensing guidance document	x	x			
	Integrate NERRS monitoring data with national and regional IOOS efforts	Partners use NERRS real-time and archived data	x	x	x	x	x
2. Scientists conduct estuarine research at reserves that is relevant to coastal management needs and increases basic understanding of estuarine processes.	Revise Graduate Research Fellowship (GRF) priority research areas	Updated GRF focal areas	x	x			
	Revise NERRS Research Database that archives and tracks research projects with the NERRS	Functional NERRS Research Database	x				
	Populate NERRS Research Database with research projects that are occuring or have occurred in the recent past (5 years) at reserves	Current, ongoing, and past research projects with NERRS are archived	x	x	x	x	x
	NERRS works with CICEET to improve coordination and delivery of relevant science	NERRS research products are accessible, CTP workshops deliver information to broad user audiences	x	x	x	x	x
	Complete a regional and/or national assessment of NERRS environmental conditions	A NERRS "Report Card" document			x	x	
3. Scientists have access to NERRS datasets, science products and results.	CDMO capabilities are assessed in relation to expanding NERRS data collection and delivery needs	CDMO and ERD identify options to manage increasing data loads and data visualization needs	x	x	x		
	NERRS Research Database is available for public access onlinez	Searchable database of research projects is available online for public access/information	x	x			
	A NERRS Special Journal Issue is published to highlight biological monitoring and research in the field	Published Special Journal Issue		x			
	A NERRS Special Journal Issue is published to highlight NERRS Habitat mapping/Land use change monitoring and remote sensing research	Published Special Journal Issue					x
	Develop a method to deliver biological monitoring and habitat mapping information to the public through CDMO	Biomonitoring information and habitat maps are made available to the public	x	x	x		
4. The scientific, coastal management and education communities, as well as the general public, use data, products, tools, and techniques generated at the NERRS.	Regularly evaluate NERRS Research priority needs	Up-to-date NERRS research priorities		x		x	
	Revise and update SWMP Plan	Revised SWMP Plan	x	x			
	Conduct a SWMP External Review	Evaluated program to guide future development	x	x			

* Some milestones and products will require additional resources.

Appendix 2: NERRS Research and Monitoring Plan

www.nerrs.noaa.gov

Appendix 3: North Carolina Coastal Habitat Protection Plan – Reseach and Monitoring Needs

RESEARCH AND MONITORING NEEDS IDENTIFIED BY THE NORTH CAROLINA COASTAL HABITAT PROTECTION PLAN

BY

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August 2005

Introduction

With passage of the Fisheries Reform Act of 1997, the North Carolina General Assembly established the Coastal Habitat Protection Plan (CHPP) program within the North Carolina Department of Environment and Natural Resources (DENR). The Act (General Statute 143B-279.8) requires preparation of a Coastal Habitat Protection Plan, the goal of which is "long-term enhancement of coastal fisheries associated with each coastal habitat." The divisions of Marine Fisheries (DMF), Water Quality (DWQ), and Coastal Management (DCM) were designated as the lead agencies for the development of the CHPP document. Specifically, the CHPP is to:

- Describe fisheries habitats and their biological systems;
- Evaluate the functions, fisheries' values, status, and trends in the habitats;
- Identify existing and potential threats to the habitats and impacts on coastal fishing; and
- Recommend actions to protect and restore the habitats.

To fully attain the CHPP goal, numerous research and monitoring needs were identified by the CHPP Development Team [including staff from the DMF, DWQ, and DCM, the Division of Environmental Health (DEH), and the Wildlife Resources Commission (WRC)] and suggested in the CHPP. By December 31, 2004, the three regulatory commissions responsible under the Act formally adopted the CHPP (Street et al. 2005), including the research and monitoring needs contained therein. The purpose of this research report is to summarize these research and monitoring needs to encourage and facilitate acquisition of this information by the research community. Meeting these research and monitoring needs will aid in implementation of CHPP recommendations.

Current related initiatives

The necessity for conducting cooperative, integrative research and monitoring in coastal settings has been cited in documents recently released by various organizations.

A report generated by the Pew Oceans Commission in May 2003 proposed the following:

"We know the oceans are in crisis. Unfortunately, as the nature, scale, and complexity of threats to marine ecosystems have increased, our national investment in ocean science and research has stagnated…The nation must increase investment in ocean science and research, particularly broader programs to monitor and to understand ecosystems…We need a deeper understanding of the effects of both natural and anthropogenic change on marine ecosystems as well as of the oceans' interaction with terrestrial ecosystems and the atmosphere. Increased capacity is needed in four areas to improve applied ocean science and research:

1. acquisition of new information, knowledge, and understanding;
2. monitoring to evaluate status and trends;
3. capability to integrate and synthesize existing and new information;
4. sharing of information and knowledge with the public."

Released in September 2004, the report of the U.S. Commission on Ocean Policy similarly recommended that the National Oceanic and Atmospheric Administration (NOAA) create an expanded, regionally-based cooperative research program that coordinates and funds collaborative projects between scientists and fishermen.

More recently, another federal document, the Environmental Protection Agency's National Coastal Condition Report II (EPA 2005), emphasized the importance of coordinated monitoring efforts within coastal habitats. The report noted that while trying to make best use of available data to characterize and assess estuarine systems, the assessment was based on a limited number of ecological indicators for which consistent data sets were available to support estimates of ecological condition on regional and national scales. The report goes on to say that a multiagency and multistate effort is needed over the continuing decade, to achieve a truly consistent, comprehensive, and integrated national coastal monitoring program that can accurately assess the health of coastal ecosystems.

In North Carolina, the CHPP identifies topics for coordinated interagency research. Because North Carolina's coastal fishery resources exist within a system of interdependent habitats, it is necessary to approach habitat management on the basis of ecosystem integrity and understanding the linkages among all coastal habitats and the outside forces that affect them. Research needed to provide the basis for ecosystem management is, of necessity, multi-disciplinary. In addition, it is also recognized that no environmental issue can be fully evaluated without considering the economic impact of alternative management actions designed to minimize degradation of the ecosystem. Determining effective management actions will thus require the integration of biological, chemical, physical, social, economic, legal and political sciences.

CHPP Research and Monitoring Needs

Table 1 describes research and monitoring needs identified directly or indirectly within the CHPP document. The purpose of Table 1 is to provide researchers and managers a quick reference guide to support their research/monitoring proposals with needs identified in the CHPP text. Thus, there are page references that serve to provide additional context for each research/monitoring need. For the purpose of clarification, the text of selected research and monitoring opportunities has been rephrased from their appearance within the CHPP, so that particular concepts may better function as discrete, "stand alone" ideas.

The research and monitoring needs in Table 1 are grouped into the following categories:

- Stormwater runoff
- Strategic Habitat Areas
- Fish-habitat relationships
- Docks and marinas
- Estuarine erosion and shoreline stabilization
- Boating related
- Beach nourishment
- Fishing gear impacts
- Managing non-native species

- Chemical effects
- Water supply
- Habitat status and trends
- Evaluating existing management measures
- Comprehensive water quality monitoring

Unfortunately, no fuding mechanisms have been developed specifically intended to support these identified needs. Interested researchers should pursue all available funding sources. The members of the CHPP development team identified in the CHPP are available to discuss these research and monitoring needs.

Literature Cited

Environmental Protection Agency. 2005. National Coastal Condition Report II. EPA-620/R-03/002. Office of Research and Development/Office of Water, Washington, DC. 271 p.

Pew Oceans Commission. 2003. America's Living Oceans: Charting a Course for Sea Change. A Report to the Nation. Pew Oceans Commission, Arlington, VA. 144 p.

Street, M.W., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. 2005. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC. 656 pp.

U.S. Commission on Ocean Policy. 2004. An Ocean Blueprint for the 21st Century. Final Report of the U.S. Commission on Ocean Policy - Pre-Publication Copy. Washington, DC. 455 p plus appendices.

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Stormwater runoff	***The major cause of water quality degradation in coastal North Carolina today is stormwater runoff. While methods to control direct discharges to surface waters have greatly improved over time, there are still many questions concerning the interaction of stormwater runoff and fish habitat, and how to effectively control non-point runoff of pollutants. Research is needed to identify the causative relationships between ecosystem conditions and land cover, hydrology, and runoff characteristics. Identifying causative relationships will allow managers to predict the impact of increasing development on coastal ecosystem conditions and prescribe management actions.***			
	Complete watershed mapping of hydrology/land cover and monitoring of downstream water quality in order to build models predicting runoff characteristics. Water quality parameters measured should include those determined to affect the survival of sensitive biological indicators (e.g. submerged aquatic vegetation, oysters).	R-M	*49, 69, *75, 77, *88-89, 109-110, 135, 332, 340-343, 412	
	Determine the relationship between changes in drainage characteristics and changes in distribution and status of sensitive biological indicators in receiving waters.	R	78	
	Identify water quality parameters (e.g., TSS, chlorophyll a, nutrients, color) and standards (e.g. average concentration, variation in concentration) that are necessary to support sensitive biological indicators.	R	34, 63, 66, 80, 89, 115, 127, 131, 224-225, *257, *274, *286-287, 335, *340, *472	
	Assess the conditions and ecological functions of black water ecosystems to determine their value as strategic buffers/filters between upland runoff and coastal fisheries habitats.	R-M	319	
	In blackwater swamp systems, assess dissolved oxygen (DO) levels and associated biological impacts, differentiating between DO derived from inflow of swamp waters and DO derived from anthropogenic nutrient loading.	R-M	34-35, 64, 85, 89, 100, *101, *103-104, *223-224	
	Evaluate the cumulative amount and extent of land cover and hydrological changes that can be accommodated by natural ecosystems before reaching some critical threshold of change in ecosystem integrity* within a watershed. ***Ecosystem integrity** is the capability of a system to support services of value to humans.	R	86, 88	
	Determine stormwater control strategies needed to prevent watersheds from reaching the critical threshold of change in ecosystem integrity.	R	79, *88, *100, *111-112, 131	
Strategic Habitat Areas	***All aquatic areas are important for the propagation and production of fish and shellfish resources. However, some specific areas stand out as being of key importance for certain species or biological communities, and the overall maintenance of ecological stability. Identification of these Strategic Habitat Areas (SHAs) is a high priority, but we lack sufficient data and tools to fully identify them. Research items below were noted in the CHPP as being necessary to help fill these information gaps so that North Carolina's coastal ecosystem can be adequately protected.***			
	Develop ecologically based criteria for locating and defining SHAs, including biological indicators of ecosystem integrity.	R	62, 268, *292, 462, 466, *483	Advisory Committee established

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Strategic Habitat Areas	Expand and improve juvenile fish sampling programs to provide regional information on status and trends in juvenile utilization of various types of nursery habitat and their contribution to production of fishery stocks. This information could serve as a basis for identifying or validating important strategic habitat areas.	M	263, *272, *380, 383-384	
	Develop techniques/technology to improve and expedite aquatic habitat mapping in order to identify the spatial extent of SHAs.	R	*483	Being addressed by shell bottom and SAV mapping
	Determine if and where foraging or refuge habitat is more limiting to fish production for that area than spawning or nursery habitat.	R	61-62, 209-210, 266, 268, 324-325, 375, 381, 458, 481	
	Identify important spawning areas for key fishery species and demonstrate their importance in terms of contribution to fisheries production.	R	53, 209, 266, 326, 378, 458, 481	
	Assess use and importance of nearshore hard bottom areas as spawning or secondary nursery areas for estuarine-dependent or reef species.	R	*458-459	
	Determine if there are core habitat areas that are key to submerged aquatic vegetation (SAV) expansion, particularly in the Albemarle Sound system, that justify special monitoring and protection.	R	*272	
Fish-habitat relationships	***There are many gaps in information regarding the specific relationships between habitat characteristics and viable fish populations. Few clear cause and effect relationships have been demonstrated between changes in habitat condition and status of fish populations due to the complexity of the coastal system and lack of data. A better understanding of fish-habitat relationsips is the cornerstone to fish habitat protection.***			
	Determine the effect of bivalve shellfish location and filtering capacities on water quality parameters, such as nutrients, sediments, and chlorophyll a.	R	*108, 204	
	Evaluate recruitment enhancement of oysters and other key organisms provided by low-density cultch planting in nursery areas.	R	*210	
	Fully evaluate the role of SAV in the spawning success of red drum, weakfish, spotted sea trout, and other important species.	R	*266	
	Determine spatial and biological characteristics of SAV beds that maximize their ecological value to important finfish and invertebrate species. This information will aid in design of seagrass restoration projects and location of SHAs.	R	*267	
	Examine the effect of spatial connectivity between habitats (ie. marsh edge and SAV) on juvenile predatory fish use, survival, growth, and abundance (i.e. red drum, spotted seatrout).	R	216, *269, *326, 381	

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Fish-habitat relationships	Determine if long-term declining trends in bay scallop and blue crab populations are related to declines in, or degradation of, SAV.	R-M	*272	
	Determine what pocosin areas are directly used by estuarine fishes, and the contribution of those areas and fish to overall production in the estuary.	R	*322	
	Assess if reef fish populations in North Carolina are limited by the amount of available hard bottom habitat by comparing differences in fish abundance before and after artificial reefs are added using a Before-After-Control-Impact Paired Series (BACIPS).	R	*463	Coordinate with similar work
	Determine if and to what extent artificial reefs in North Carolina simply concentrate available fish or if they effectively increase fish biomass.	R	*463	
	Determine the critical frequency and extent of hypoxia and anoxia, above which significant changes in biotic community structure occur.	R-M	104, 223, 318	
	Determine the critical amount and quality of living and dead shell bottom in a water body below and above which significant changes in biotic community structure (e.g., SAV, oyster reef) occur.	R-M	*215	
	Identify biological indicators of ecosystem integrity that also indicate viable populations of traditional fishery species.	R	13, 135, 262, 289, 372	Coordinate with existing work (APNEP)
	Locate potential SAV and oyster restoration sites using a combination of seed/larval transport, water quality, physical habitat models, coincidence with watershed restoration efforts, and other available information.	R	*218, 224, 230, *257, *267, *272	Coordinate with existing work
Docks and Marinas	***As coastal, human population increases, there is a continuing demand for additional individual and multi-slip boat docking facilites and marinas, and decreasing availability of highly suitable locations. More answers are needed regarding the direct, indirect, and cumulative effects of these facilities and their use on fish habitat so that future dock and marina siting guidelines can minimize habitat impacts.***			
	Determine if marina basins in freshwater and low-salinity nursery areas produce toxic chemicals at sufficient concentrations and critical times to impact local fish populations (especially considering egg and larval life stages).	R-M	118, *121	
	Determine if existing dock siting criteria allow adequate light beneath dock structures to maintain SAV and coastal wetland habitat. If existing criteria result in adverse effects on SAV or coastal wetlands, modified dock siting specifications that allow adequate light penetration should be identified.	R	*279	Preliminary DMF research available
	Analyze marina development, design, siting and operation to determine the best management practices to minimize impacts of multi-slip docking facilities.	R	*123	Advisory committee established (Sea Grant)

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Docks and Marinas	Quantify the cumulative effect of multi-slip docking facilities and associated development on water quality, characteristics of runoff, and the impacts on adjacent fish habitat.	R-M	*125, *279, *391	Advisory committee established (Sea Grant)
	Evaluate the impact of dock-associated prop dredging on shallow nursery habitats.	R-M	*391	
Boating related	***In addition to the effects of docking structures, information is needed on the individual and cumulative effects of boat use on coastal waters and habitat. As boat use changes over time, additional information may also be needed.***			
	Assess the impact of jetties on successful larval passage through inlets into estuaries, particularly in Pamlico Sound where inlets are limited.	R-M	*83	
	Examine the relative contribution of channel deepening to saltwater intrusion and evaluate subsequent oyster mortality (i.e. from predation) in order to determine appropriate management actions.	R-M	*228	
	In areas of heavy boat traffic and extensive SAV beds, periodically assess the level of damage to SAV from prop scarring.	R-M	*277	Some NOAA work
	Determine what effect the Ocean Dredge Material Disposal Site (ODMDS), located near the mouth of the Cape Fear River, has had or will have on nearby hard bottom habitat.	R	*469	
	Determine the impact of chronic oil pollution from boating and runoff on estuarine nursery areas.	R-M	*122-123	
	Determine the impact of waves propagated from boat operations on adjacent marsh and shell bottom shorelines.	R-M	*222, *350	
Estuarine erosion and shoreline stabilization	***Shallow water habitats adjacent to the estuarine shoreline are critical to North Carolina's coastal fish populations. Therefore, managing shoreline stabilization activities in a manner that minimizes habitat impacts is an important issue. Research that aids in understanding shoreline processes and the effect of man-made structures on the estuarine environment will help in implementing the CHPP recommendation to revise estuarine and public trust shoreline stabilization rules for protecting fish habitat.***			
	Periodically assess where and how much of the estuarine shoreline is hardened. Accurate information is key to assessing the level of impact to fishery resources.	M	*347	Preliminary DMF research available
	Examine if and how oyster shell could be utilized as an alternative to rock or wooden stabilization structures to create “living shorelines” that are effective in stabilizing the shoreline.	R-M	*349, *392	
	Develop accurate coast-wide estuarine erosion rates to assess sea-level rise and storm impacts, determine adequate development guidelines, and shoreline stabilization policies that minimize impacts on fish habitat (e.g., soft bottom, wetlands, shellfish).	R-M	*105, *349	DCM workgroup discontinued

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Beach nourishment	***The demand for beach nourishment projects has greatly increased in recent years. It is therefore increasingly important to fully understand the long-term consequences of this activity to the coastal system and fish populations, so that an ecologically based, comprehensive beach and inlet management plan can be prepared, per the CHPP recommendation.***			
	Compile detailed mapping studies of coastal subtidal bottom in a comprehensive and comparable manner in order to evaluate changes and trends in substrate character.	R-M	*370	Pilot project completed
	Determine if and to what extent sand from nourished beaches is transported onto nearshore hard bottom and the effect of sand deposition on the hard bottom habitat and associated biological community.	R-M	*465	
	Assess the cumulative impact and effectiveness of beach bulldozing and determine appropriate guidelines for inclusion in a coastal beach management plan.	R-M	*393	One study completed
	Assess direct and indirect effects, and cumulative impacts of beach nourishment activities on surf-zone organisms (finfish and invertebrates), their habitats and recovery rates from individual and cumulative nourishment events.	R-M	*398, *402	
Fishing gear impacts	***While most bottom disturbing fishing gears have been restricted from use in highly sensitive areas, the effect of some gears is still uncertain, and more information is needed to determine needed fishery management changes. Information regarding fishing gear impacts will help implement the CHPP recommendation to protect structured habitats from fishing gear effects.***			
	Measure in situ rates of growth, mortality, and recruitment for selected benthic organisms that are regularly exposed to trawling.	R	*405	
	Evaluate the effect of trawling on benthic algal growth and primary productivity overall.	R	*405	
	Conduct large-scale, long-term experiments with and without fishing pressure, rather than short-term, small-scale studies, to examine and quantify cumulative fishing impacts and recovery patterns on estuarine soft bottoms and benthos.	R-M	*407	
	Monitor the impact of hook and line fishing and anchoring on hard bottom.	R-M	*467	
	Determine whether fishing gear impacts and/or other factors are causing the decline observed in bay scallop abundance.	R	*281	
	Assess turbidity impacts to SAV from mechanical shellfish harvesting gear in southeast Pamlico Sound, Core Sound, and other mechanical clam harvest areas.	R-M	*282	
	Assess the effects of shrimp and crab trawling; crab, oyster, clam, or scallop dredging; and clam kicking on SAV, particularly in Core and Bogue sounds.	R-M	*284	
	If turbidity or other gear impacts from operation of bottom disturbing fishing gear degrades nearby SAV habitat, determine what additional protective buffers are needed between SAV and areas where such gear are used in order to minimize impacts.	R	*292	
	Identify the location and duration of trawling over soft bottom habitat, as well as over structured habitats (shell bottom, hard bottom and SAV), and quantify the effects of trawling on the habitats.	R-M	*405	
	Determine turbidity levels generated by different commercial fishing gear configurations and the subsequent rates of redeposition at various distances from the origin under varying wind and current conditions.	R	*405	

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Fishing gear impacts	Compare the significance of natural forms of disturbance on soft bottom habitat to that of trawling effects on soft bottom habitat.	R-M	*405	
	Sample areas normally subjected to trawling to describe the local benthic community, identifying seasonal cycles of species abundance and recruitment, to determine the times of year that benthos would be most sensitive to trawling disturbance.	R-M	*405	
Managing non-native species	***The accidental or intentional introduction of non-native species is a growing issue in natural resources management. Understanding the effect of non-native species on the ecological integrity of our native ecosystems is necessary for effective ecosystem management.***			
	Conduct testing on the aquacultural use of non-spawning, non-native oysters before decisions are made opposing or supporting introduction.	R	*229	Research ongoing
	Compare the fish habitat value of Eurasian watermilfoil relative to native vegetation.	R	*291	
	Develop ways to prevent proliferation of non-native species by sterilizing ballast water, testing non-native species before introduction, and assessing legal mechanisms to prevent introductions.	R-M	*129	
Chemical effects	***Growing use and disposal of chemicals in support of modern lifestyles has undoubtedly had an effect on the viability of organisms in receiving waters. While there is some information available on the toxicity of certain chemicals to selected organisms, under certain conditions, more work is needed to fully evaluate the potential impact of chemical pollution on fisheries resources.***			
	Identify pesticides that are "safe" for spraying over open waters, and for those pesticides whose toxicity is impacted by salinity, appropriate application rates for controlling mosquitoes.	R	*125	
	Determine the sources, prevalence, and effects of hormone-altering chemicals on important fish species in North Carolina's coastal waters.	R-M	*118	
	Examine the effects of existing contaminant levels and other environmental stressors on water quality, benthic food organisms, and fish.	R-M	118, 224, *411, *469	
	Evaluate the biological impact of any new materials (wood, plastic, cement, etc.) used in water-dependent structures on the aquatic ecosystem.	R	*121, *226	
Water supply	***With increasing demands for fresh water, the allocation of existing water resources among direct human uses and the needs of native fish and wildlife species is becoming an increasingly difficult issue.***			
	Assess the impact of increasing municipal, industrial, and/or agricultural surface water withdrawals as well as reservoir management on instream flows (water column habitat) on dependent anadromous fish populations in coastal rivers.	R	*73	
	Assess groundwater supplies in coastal counties to determine the potential environmental consequences of increasing subsurface water withdrawals.	R-M	*74	
	Determine effects of brine effluent disposed from filter backwash and reverse osmosis water treatment facilities on biological communities in coastal receiving waters.	R-M	*128-129	

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Habitat status and trends	***Determining the status and trends in condition of fish habitats is vital in evaluating the need and effectiveness of management actions intended to protect them.***			
	Conduct change analysis of existing shell bottom by DMF's Shellfish Habitat and Abundance Mapping Program on a subset of priority areas. Prioritization should include consideration of functional significance, economic value, and the magnitude of growth and development affecting the area.	R-M	*211	
	Determine the status of hard clams, sheepshead, black drum, and resident non-fishery species (e.g., oyster toadfish) as indicators of shell bottom conditions, using fisheries-independent-data.	R-M	*215	
	Evaluate status and trends in coast-wide distribution and condition of SAV at regular intervals. Comprehensive maps of all existing and potential SAV habitat should also be developed.	M	*272, *291	Workgroup established
	Determine wetland restoration success criteria based on long-term monitoring of hydrology, soil, and vegetation characteristics at established reference sites.	R-M	*332	Coordinate with EEP
	Determine the cumulative impact of small wetland losses on the distribution and abundance of wetland types in selected watersheds. The cumulative losses could then be related to the nature and extent of development pressure in those watersheds in order to formulate a model predicting untracked losses in other watersheds.	R-M	*339	
	Evaluate the susceptibility of freshwater wetlands to soil loss from sulfate metabolism in coastal North Carolina.	R	*352	
	Use biological indicators of habitat condition and coastal ecosystem integrity to help determine overall status and trends for the coastal ecosystem in North Carolina.	M	13, 17-19, 64, 66, 104, 135, 215, 223, 262, 289, 318, 372	Workgroup established
Evaluating existing management measures	***Prior to establishing new or additional management measures, resource agencies must first evaluate and determine if existing management measures are adequate and effective in achieving their intended management goals.***			
	Evaluate the functional viability of shellfish (primarily oysters) in closed shellfishing waters and their value as protected shell bottom habitats.	R-M	*231	
	Assess the N.C. Pesticide Board's policies on aerial drift of pesticides and suggest changes if necessary to ensure adequate protection for aquatic life and water quality from pesticide impacts.	R	*126	
	Evaluate water quality conditions and effectiveness of the nutrient reduction strategies in the Neuse River and the Tar-Pamlico River.	R-M	*133	On-going
	Evaluate effectiveness of ORW and HQW rules in protecting SAV and other habitats.	R-M	135, *292-293, *337	
	Evaluate the CRC's beach nourishment rules and determine changes needed to minimize impacts from beach nourishment and dredge disposal on soft bottom communities.	R	*277	

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Table 1. Research needs identified in the North Carolina Coastal Habitat Protection Plan.

Issue	Description of Need	Type^	CHPP page reference*	Status (Aug 05)
Evaluating existing management measures	Examine and propose revisions to current CRC shoreline stabilization rules using best scientific information to minimize impacts from this activity to soft bottom and wetlands, particularly intertidal estuarine shorelines.	R	*391-392	
Comprehensive water quality monitoring	***The overall status of water quality in North Carolina has been difficult to evaluate because of the variety of uncoordinated water quality monitoring efforts covering different areas over different time periods. The gaps in completing a comprehensive evaluation of coastal water quality are many. Some of these needs were noted in the CHPP and are listed below.***			
	Expand water quality monitoring in North Carolina's nearshore ocean waters to improve our understanding of existing conditions and processes in coastal waters and the effect of estuarine inputs and human activities on local water quality.	M	*66	
	Assess water quality trends and causes of degradation in tidal creek systems, particularly in southern coastal counties that are highly important nursery and shellfish areas and are under intense development pressure, and determine effective preventive and restoration measures.	R-M	*100-101	
	Monitor the effect of estuarine water quality, particularly nutrient and sediment loading, on nearshore ocean hard bottom.	R-M	*469	
	Additional water and tissue analysis at hard bottom sites is needed to determine if the benthos of the hard bottom community or the surrounding waters exhibit toxin levels that exceed designated levels of concern.	M	*469-470	
	Assess the impact of historic and recent wetland drainage activities on coastal water quality.	R-M	*80, 222, *340	
	Assess the effects that oceanfront septic systems have on nearshore coastal water quality.	R-M	*116	
	Once the appropriate water quality conditions for protection of SAV are determined, current water quality monitoring stations and methods should be re-evaluated and modified (if necessary) so that data adequately assess if SAV-based water quality criteria are being met (both baseline and potential SAV habitat). The Neuse, Tar-Pamlico and White Oak basins should be a high priority for monitoring of SAV and water clarity.	R-M	*287	Contingent on research results

^R=Research, M=Monitoring, and R-M=Research that can form the basis of monitoring
*Specific research need extracted from the CHPP (wording very similar).

Appendix 4: NERRS Habitat Classifications and Land Cover Protocols

Appendix 4: Habitat Classification and Land Cover Protocols

4.1: Habitat Classification Methods

A primary objective of SWMP Phase 3 is to evaluate changes over time in estuarine habitats and coastal land cover. Initial activities in accomplishing this are to document baseline conditions of habitats within the Reserves and land cover conditions for watersheds associated with the Reserve components. In support of these efforts, the NERRS has recently adopted a habitat classification scheme to consistently describe ecosystems throughout the Reserve System and at various levels of detail (Kutcher et al. 2005). The NERR Habitat Classification scheme is a modified combination of classification schemes established for the U.S. Geologic Survey (Anderson et al. 1976), U.S. Fish and Wildlife Service (Cowardin et al. 1979) and NOAA Coastal Change Analysis Program (C-CAP 2004). The NERR Habitat Classification scheme uses a nested hierarchical structure to describe habitat and land cover conditions at 5 levels of detail: System, Subsystem, Class, Subclass, and Descriptors. Each habitat category is assigned a unique numerical code for each hierarchical level (see Section 4.6). This allows the classified data to be efficiently analyzed and summarized at any of the 5 levels. For example, a stand of *Spartina alterniflora* would be assigned labels as presented in Table 4.1. Additional modifiers may also be designated by a Reserve to describe unique local habitat conditions.

Table 4.1. Hierarchical Classification Labels for *Spartina alterniflora.*

Level	Code	Label
System	2000	Estuarine Habitat
Subsystem	2200	Estuarine Intertidal Haline
Class	2260	Estuarine Intertidal Haline Emergent Wetland
Subclass	2261	Estuarine Intertidal Haline Emergent Wetland - Persistent

Initially, the NCNERR conducted a pilot project at the Zeke's Island component to evaluate the NERR Habitat Classification scheme and to develop standardized methods for consistent application of the scheme. The protocols and scheme were subsequently used to classify habitats for the Masonboro Island, Rachel Carson and Currituck Banks NCNERR components.

The NCNERR habitat classification approach alternated between field surveys and digital image analyses (see Table 4.2). Habitat analyses and area calculations were conducted using ESRI GIS software. Habitat features were digitally delineated from best-available ortho-rectified True Color aerial photography collected in 2002 and 2004. Ancillary information was provided by digital Color Infrared (CIR) imagery collected in 1998. The CIR data depict differences in substrate moisture content and vegetation chlorophyll *a* levels. These data are helpful for distinguishing upland from estuarine and marine conditions, and plant species with different leaf morphologies.

Non-aquatic habitat features were mapped if they covered an areal extent equal to or greater than a minimum mapping unit (mmu) of approximately 1/4 acre (100' x 100'). Linear and small features were delineated if they were greater than, respectively, 10' x 50' or 50' x 50' and were deemed to be ecologically significant. Each habitat feature was defined as a polygon with

associated labels (attributes) for each of 4 hierarchical classification levels: System, Subsystem, Class and Subclass. Descriptor (level 5) labeling of habitat features requires more extensive field surveys and will be added in the future as time and priorities allow. Maps and analysis of the habitat classification for each Reserve component are provided in their respective chapters. Section 4.3 includes pictures and descriptions of habitat subclasses found in the NCNERR.

Table 4.2. NCNERR habitat mapping approach during pilot project

Step	Description
1	**Identification and acquisition of best-available digital aerial images: 2002 and 2004 True Color aerial photos (0.5' – 2' resolution); ancillary 1998 Color Infrared imagery (3.3' resolution).**
2	**Initial field survey to document conditions and geocoordinates of representative patches of habitat types. The survey data are used as habitat "signatures" as an aid for aerial photo interpretation.**
3	**Initial digital delineation of habitat polygons. Spatial definition was based on the 2002 - 2004 True Color aerial photography. Habitat labeling incorporated additional moisture and chlorophyl level information from the 1998 Color Infrared imagery.**
4	**Calculation of areal statistics, based on the preliminary habitat classification.**
5	**Field check of preliminary habitat map to confirm delineations that are confident and resolve those that are uncertain.**
6	**Revision of habitat delineations and labels based on the field check.**
7	**Field check of revised habitat classification, to verify delineation and labeling.**
8	**Preparation of distribution-quality map of final habitat classification.**
9	**Calculation of areal statistics using final habitat data.**
10	**Reserve staff review of habitat map and areal statistics.**
11	**Preparation of final habitat map, statistics and graphics.**

The classification identified 26 subclasses in 5 habitat systems within the NCNERR. Habitat occurrence for the four NCNERR components is presented in Table 4.3 as the percent of the site total (non-aquatic acres) for each subclass. The values for the three most prevalent habitat subclasses are circled for each site. Statistics represent habitat distribution as delimited by the anthropogenic management boundaries of the Reserve, rather than natural boundaries such as watersheds. NCNERR Habitats are summarized as follows:

- Approximately half of the non-aquatic habitat area at the Rachel Carson, Masonboro Island and Zeke's Island Components is Estuarine Intertidal Persistent Wetland. This is primarily *Spartina alterniflora*. For Currituck Banks, Estuarine Supratidal Persistent Wetland is predominate, identified as 17% of the habitat area. The major species is *Spartina cynosurides*.

- The second most prevalent habitat is variable by site, including Upland Supratidal Sand (Dune) at Masonboro Island and Zeke's Island, and Estuarine Intertidal Sand at Rachel Carson. At Currituck Banks, Upland Supratidal Forest Mixed covers 11% of the area, the largest percentage of forest within the Reserve.

- Upland Supratidal Grassland is the third most common habitat for 3 sites: Rachel Carson, Masonboro Island and Zeke's Island. Palustrine Intermittent Scrub-Shrub Broad Leaf Deciduous is present only at Currituck Banks, where it is the third most prevalent habitat.

- Occurrence of habitats is similar between the three southern sites (Rachel Carson, Masonboro Island and Zeke's Island) and different from Currituck Banks. Distribution is strongly influenced by site hydrology. The southern sites have regular lunar tides of the Atlantic Ocean. Currituck Banks is irregularly flooded by wind-driven tides of Currituck Sound. Currituck Banks is the only site with Palustrine Non-tidal Freshwater Wetlands.

- The three southern sites and Currituck Banks are situated, respectively, in the Carolinian and Virginian Biogeographic Provinces. Biogeographic parameters may impact species composition and habitat occurrence. The habitat classification provides a framework for more detailed vegetation inventories and investigation of species distribution.

The NCNERR classified habitats support the following coastal resource management activities:

- Identify sensitive habitats to guide component access, in combination with Visitor Use Surveys.

- Quantify acreages of habitats that are protected within the Reserve. This will support the North Carolina Strategic Conservation Plan, help guide future property acquisition, and ensure that coastal diversity is protected.

- Provide a baseline to assess changes due to natural or anthropogenic effects including sea level rise and climate change.

- Support cross-walk between other classification schemes to understand broader ecosystem classification.

Table 4.3. Habitat Occurrence (% of Site Total of Non-Aquatic Acres)

SYSTEM	SUBSYSTEM - SUBCLASS	Currituck Banks	Rachel Carson	Masonboro Island	Zeke's Island
Cultural Land Cover	CLC Paved Road	0.09			
Cultural Land Cover	CLC Permeable Lot	0.03			
Cultural Land Cover	CLC Rocky In-Water Structure			0.06	0.44
Estuarine	Est. Intertidal Mud				0.21
Estuarine	Est. Intertidal Persistant Wetland		**40.44**	**58.43**	**56.13**
Estuarine	Est. Intertidal Reef Mollusk		0.01		
Estuarine	Est. Intertidal Sand		**30.15**	1.43	3.93
Estuarine	Est. Intertidal Scrub-Shrub BLD			1.81	4.08
Estuarine	Est. Subtidal Organic				0.02
Estuarine	Est. Subtidal Sand			0.30	0.85
Estuarine	Est. Supratidal Persistant Wetland	**17.32**	2.71	4.07	0.77
Estuarine	Est. Supratidal Sand		3.62	3.78	
Estuarine	Est. Supratidal Scrub-Shrub BLD	3.94	3.53	4.74	3.17
Estuarine	Est. Supratidal Scrub-Shrub BLE	2.10	0.13		
Marine	Marine Intertidal Sand	4.42		5.16	3.35
Palustrine	Pal. Intermittent Forest BLD	9.41			
Palustrine	Pal. Intermittent Persistant Wetland	2.12			
Palustrine	Pal. Intermittent Scrub-Shrub BLD	**10.25**			
Palustrine	Pal. Intermittent Scrub-Shrub BLE	6.21			
Upland	Upld. Supratidal Forest BLE	6.52	0.24	0.12	0.02
Upland	Upld. Supratidal Forest Mixed	**11.04**	0.04		
Upland	Upld. Supratidal Forest NLE	2.17			
Upland	Upld. Supratidal Grassland	7.93	**8.43**	**7.64**	**9.96**
Upland	Upld. Supratidal Sand	3.14	3.13	**7.83**	**11.96**
Upland	Upld. Supratidal Scrub-Shrub BLD	5.67	0.22	0.33	1.49
Upland	Upld. Supratidal Scrub-Shrub BLE	7.46	6.82	4.20	4.49
Upland	Upld. Supratidal Scrub-Shrub NLE	0.16	0.27	0.45	
	Habitat Prevalence per Site:	**First**	**Second**	**Third**	

4.2: Land Cover Methods:

Land Cover conditions are being examined for the watersheds associated with each of the 4 NCNERR components. For this effort, watersheds were defined as US Geologic Survey 8 digit Hydrologic Cataloguing Units, to be compatible with Land Cover information from other NERRs. Synoptic Land Cover data sets were obtained for coastal North Carolina from NOAA's Coastal Change Analysis Program (C-CAP). These data sets are currently available for 1991, 1997 and the changes between the two years. Analysis methods were developed using the Zeke's Island Component and were repeated for the other 3 NCNERR sites. First, each data set (1991, 1997 and 1991 – 1997) was clipped to the geographic extent of the watershed boundary then area distribution of Land Cover Classes and % Total area were calculated. To portray 1991-1997 changes in a meaningful way, the data were combined into 3 categories: 1) Increased Vegetative Cover, 2) Decreased Vegetative Cover and 3) Different Unvegetated Class. The decrease in vegetation cover category includes all areas where the Land Cover changed between 1991 and 1997 to a class that characterizes conditions with generally less plant cover or biomass. Examples of this category are a transition from Forested to Grassland or Scrub-shrub to Low Density Development. The increase in vegetation cover category was assigned to all areas where the Land Cover changed to a class that represents generally greater plant cover or biomass. Examples of this category are succession of grassland to Scrub-Shrub and Scrub-Shrub to Forested. The change in non-vegetated cover category designates all areas that had different non-vegetated land cover classes in 1991 and 1997. Examples included water to unconsolidated shore, unconsolidated shore to bare land and bare land to low-density developed. Land Cover maps and summaries are presented in the stressors section of the respective chapters for each component.

4.3: Habitat Subclasses found in the NCNERR

1000. Marine Habitats

Marine Intertidal Sand (1243): This subclass represents areas of bare sand between high and low tide lines and is commonly referred to as "The Beach".

2000. Estuarine Habitats

Estuarine Subtidal Sand (2123):
This habitat type is submerged bare sand found in small ponds within areas of higher ground.

Estuarine Subtidal Organic Unconsolidated Bottom (2125):
This habitat type includes organic substrate, not fully exposed at low tide, found beneath small ponds within areas of higher ground.

Estuarine Intertidal Reef Mollusc (2221):
This subclass includes areas of intertidal oyster reefs, found primarily at the Rachel Carson component.

Estuarine Intertidal Sand (2253):
This subclass includes all sandy intertidal (beach) areas not directly touching the Ocean.

Estuarine Intertidal Mud (2254):
These areas, often called “mudflats”, represent bare sediments with some organic content. These areas are exposed at low tide and are highly productive feeding grounds for fish at high tide.

Estuarine Intertidal Pesistant Wetland (2261):
This habitat type is known as "Saltmarsh", exposed at low tide, they most often consist of smooth cordgrass (*Spartina alterniflora).*

Estuarine Intertidal Scrub-Shrub Broad Leaf Deciduous (2271):
The intertidal scrub-shrub subclass is dominated by sea ox-eye (*Borrichia frutescens*).

Estuarine Supratidal Persistant Wetland (2341):
This subclass is commonly called the "high marsh". It is made up of salt meadow hay (*Spartina patens*), inland saltgrass (*Distichlis spicata*), and black needle rush (*Juncus roemarianus*).

Estuarine Supratidal Scrub-Shrub Broad Leaf Deciduous (2351):
The subclass is usually adjacent to the intertidal marsh. Dominate plants in this region include: sea ox-eye (*Borrichia frutescens*), salt meadow hay (*Spartina patens)*, sea oats (*Uniola paniculata*), and inland saltgrass (*Distichlis spicata*).

Estuarine Supratidal Scrub-Shrub Broad Leaf Evergreen (2353):
This subclass includes short woody (< 20 ft) vegetation including wax myrtle (*Myrica cerifera*), holly (*Ilex cassine*) and Sweet Bay (*Magnolia viginiana*).

5000. Palustrine Habitats

Palustrine Intermittant Persistent Wetland (5232):
This subclass represents areas that are irregularly saturated with fresh water with the predominant vegetation being saltmeadow cordgrass (*Spartina patens*).

Palustrine Intermittant Scrub-Shrub Broad Leaf Deciduous (5241):
This subclass includes immature or stunted (<20 ft) forms of woody vegetation including Red Maple (*Acer rubrum),* Carolina Willow (*Salix caroliniana*), Willow Oak (*Quercus phellos*), Persimmon *(Diospyros viginiana*) and Black Gum (*Nyssa sylvatica*).

Palustrine Intermittant Scrub-Shrub Broad Leaf Evergreen (5243):
This subclass represents communities of mixed vegetation (<20 ft) that include live oak (*Quercus virginiana*), yaupon (*Ilex vomitoria*), wax myrtle (*Morella cerifera* or *Myrica cerifera*), and laurel oak (*Quercus laurifolia*).

Palustrine Intermittant Forest Broad Leaf Deciduous (5251):
These are areas of mature forest (>20 ft) with species that include Red Maple (*Acer rubrum),* Carolina Willow (*Salix caroliniana*), Willow Oak (*Quercus phellos*), Persimmon *(Diospyros viginiana*) and Black Gum (*Nyssa sylvatica*)

6000. Upland Habitats

Upland Supratidal Sand (6123):
These are areas of upland sand, with less than 30% vegetative cover.

Upland Supratidal Grassland (6131):
These grassland areas are inhabited by a mixed community of perennial beach grasses such as salt meadow hay (*Spartina patens)*, sea oats (*Uniola paniculata*), inland saltgrass (*Distichlis spicata*) and various species of *Panicum.*

Upland Supratidal Scrub-Shrub Broad Leaf Deciduous (6141):
This is a mixed community of shrub species, often referred to as "shrub thicket". Example species are marsh elder (*Iva frutescens*), and grounsel tree (*Baccharis halimifolia*).

Upland Supratidal Scrub-Shrub Broad Leaf Evergreen (6143):
The woody vegetation represented by this subclass is <20ft in height, with a mix of yaupon (*Ilex vomitoria*), wax myrtle (*Morella cerifera* or *Myrica cerifera*), laurel oak (*Quercus laurifolia*).

Upland Supratidal Scrub-Shrub Needle Leaf Evergreen (6144):
This subclass includes needle leaf shrubs (<20 ft), predominantly eastern red cedar (*Juniperus virginiana*).

Upland Supratidal Forest Broad Leaf Evergreen (6153):
This subclass is represented by stands of mature trees, greater than 20 ft in height. Species include live oak (*Quercus virginiana*), yaupon (*Ilex vomitoria*), wax myrtle (*Morella cerifera* or *Myrica cerifera*), and laurel oak (*Quercus laurifolia*).

Upland Supratidal Forest Needle Leaf Evergreen (6154):
This subclass is composed primarily of loblolly pines (*Pinus taeda*) with a small unique stand of longleaf pine (*Pinus palustris*) found at Currituck Banks.

Upland Supratidal Forest Mixed (6155):
This subclass includes a mix of mature trees, with no species occupying >75% of the community. Species may include loblolly pines (*Pinus taeda*) and broad leaf trees, including live oak (*Quercus virginiana)*, yaupon (*Ilex vomitoria*), wax myrtle (*Morella cerifera)*.

8000. Cultural Land Cover Habitats

Cultural Land Cover Rocky In Water Structures (8342):
This subclass refers to the rock wall jetties that surround the basin area at Zeke's Island, and protect Masonboro Inlet.

4.5: References

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4.6: NERR Habitat Classification Scheme (June 2006)

1000. Marine Habitats System
- 1100. Subtidal
  - 1110. Rock Bottom
    - 1111. Bedrock
    - 1112. Rubble
  - 1120. Unconsolidated Bottom
    - 1121. Cobble
    - 1122. Gravel
    - 1123. Sand
    - 1124. Mud
    - 1125. Organic
  - 1130. Aquatic Bed
    - 1131. Rooted Algal
    - 1132. Drift Algal
    - 1133. Rooted Vascular
    - 134. Faunal
  - 1140. Reef
    - 1141. Mollusk
    - 1142. Coral
    - 1143. Worm
    - 1144. Artificial
- 1200. Intertidal
  - 1210. Aquatic Bed
    - 1211. Rooted Algal
    - 1212. Drift Algal
    - 1213. Rooted Vascular
  - 1220. Reef
    - 1221. Coral
    - 1222. Worm
  - 1230. Rocky Shore
    - 1231. Bedrock
    - 1232. Rubble
  - 1240. Unconsolidated Shore
    - 1241. Cobble
    - 1242. Gravel
    - 1243. Sand
    - 1244. Mud
    - 1245. Organic

2000. Estuarine Habitats
- 2100. Subtidal Haline
  - 2110. Rock Bottom
    - 2111. Bedrock
    - 2112. Rubble
  - 2120. Unconsolidated Bottom
    - 2121. Cobble

- 2122. Gravel
- 2123. Sand
- 2124. Mud
- 2125. Organic

2130. Aquatic Bed
- 2131. Rooted Algal
- 2132. Drift Algal
- 2133. Rooted Vascular
- 2134. Floating Vascular
- 2135. Faunal

2140. Reef
- 2141. Mollusk
- 2142. Worm
- 2143. Artificial

2200. Intertidal Haline

2210. Aquatic Bed
- 2211. Rooted Algal
- 2212. Drift Algal
- 2213. Rooted Vascular
- 2214. Floating Vascular

2220. Reef
- 2221. Mollusk
- 2222. Worm

2230. Streambed
- 2231. Bedrock
- 2232. Rubble
- 2233. Cobble
- 2234. Gravel
- 2235. Sand
- 2236. Mud
- 2337. Organic

2240. Rocky Shore
- 2241. Bedrock
- 2242. Rubble

2250. Unconsolidated Shore
- 2251. Cobble
- 2252. Gravel
- 2253. Sand
- 2254. Mud
- 2255. Organic

2260. Emergent Wetland
- 2261. Persistent
- 2262. Nonpersistent

2270. Scrub-Shrub Wetland
- 2271. BLD
- 2272. NLD

- 2273. BLE
- 2274. NLE
- 2275. Dead
- 2280. Forested Wetland
  - 2281. BLD
  - 2282. NLD
  - 2283. BLE
  - 2284. NLE
  - 2285. Mixed
  - 2286. Dead

2300. Supratidal Haline
- 2310. Rock Bottom
  - 2311. Bedrock
  - 2312. Rubble
- 2320. Unconsolidated Bottom
  - 2321. Cobble
  - 2322. Gravel
  - 2323. Sand
  - 2324. Mud
  - 2325. Organic
- 2330. Aquatic Bed
  - 2331. Rooted Algal
  - 2332. Drift Algal
  - 2333. Rooted Vascular
  - 2334. Floating Vascular
- 2340. Emergent Wetland
  - 2341. Persistent
  - 2342. Nonpersistent
- 2350. Scrub-Shrub Wetland
  - 2351. BLD
  - 2352. NLD
  - 2353. BLE
  - 2354. NLE
  - 2355. Dead
- 2360. Forested Wetland
  - 2361. BLD
  - 2362. NLD
  - 2363. BLE
  - 2364. NLE
  - 2365. Mixed
  - 2366. Dead

2400. Subtidal Fresh
- 2410. Rock Bottom
  - 2411. Bedrock
  - 2412. Rubble
- 2420. Unconsolidated Bottom

- 2421. Cobble
- 2422. Gravel
- 2423. Sand
- 2424. Mud
- 2425. Organic

2430. Aquatic Bed
- 2431. Rooted Algal
- 2432. Drift Algal
- 2433. Rooted Vascular
- 2434. Floating Vascular
- 2435. Aquatic Moss

2440. Reef
- 2441. Mollusk

2500. Intertidal Fresh

2510. Aquatic Bed
- 2511. Rooted Algal
- 2512. Drift Algal
- 2513. Rooted Vascular
- 2514. Floating Vascular
- 2515. Aquatic Moss

2520. Streambed
- 2521. Bedrock
- 2522. Rubble
- 2523. Cobble
- 2524. Gravel
- 2525. Sand
- 2526. Mud
- 2527. Organic

2530. Rocky Shore
- 2531. Bedrock
- 2532. Rubble

2540. Unconsolidated Shore
- 2541. Cobble
- 2542. Gravel
- 2543. Sand
- 2544. Mud
- 2545. Organic

2550. Emergent Wetland
- 2551. Persistent
- 2552. Nonpersistent

2560. Scrub-Shrub Wetland
- 2561. BLD
- 2562. NLD
- 2563. BLE
- 2564. NLE
- 2565. Dead

- 2570. Forested Wetland
  - 2571. BLD
  - 2572. NLD
  - 2573. BLE
  - 2574. NLE
  - 2575. Mixed
  - 2575. Dead

3000. Riverine Habitats

- 3100. Lower Perennial
  - 3110. Unconsolidated Bottom
    - 3111. Gravel
    - 3112. Sand
    - 3113. Mud
    - 3114. Organic
  - 3120. Aquatic Bed
    - 3121. Aquatic Moss
    - 3122. Rooted Vascular
    - 3123. Floating Vascular
  - 3130. Rocky Shore
    - 3131. Bedrock
    - 3132. Rubble
  - 3140. Unconsolidated Shore
    - 3141. Cobble
    - 3142. Gravel
    - 3143. Sand
    - 3144. Mud
    - 3145. Organic
  - 3150. Emergent Wetland
    - 3151. Nonpersistent
- 3200. Upper Perennial
  - 3210. Rock Bottom
    - 3211. Bedrock
    - 3212. Rubble
  - 3220. Unconsolidated Bottom
    - 3221. Cobble
    - 3222. Gravel
    - 3223. Sand
    - 3224. Mud
  - 3230. Aquatic Bed
    - 3231. Algal
    - 3232. Aquatic Moss
    - 3233. Rooted Vascular
    - 3234. Floating Vascular
  - 3240. Rocky Shore
    - 3241. Bedrock
    - 3242. Rubble

- 3250. Unconsolidated Shore
  - 3251. Cobble
  - 3252. Gravel
  - 3253. Sand
  - 3254. Mud
  - 3255. Organic
- 3260. Emergent Wetland
  - 3261. Nonpersistent
- 3300. Intermittent
- 3310. Streambed
  - 3311. Bedrock
  - 3312. Rubble
  - 3313. Cobble
  - 3314. Gravel
  - 3315. Sand
  - 3316. Mud
  - 3317. Organic
  - 3318. Vegetated
- 4000. Lacustrine Habitats
- 4100. Limnetic
- 4110. Rock Bottom
  - 4111. Bedrock
  - 4112. Rubble
- 4120. Unconsolidated bottom
  - 4121. Cobble
  - 4122. Gravel
  - 4123. Sand
  - 4124. Mud
  - 4125. Organic
- 4130. Aquatic Bed
  - 4131. Algal
  - 4132. Aquatic Moss
  - 4133. Rooted Vascular
  - 4134. Floating Vascular
- 4200. Littoral
- 4210. Rock Bottom
  - 4211. Bedrock
  - 4212. Rubble
- 4220. Unconsolidated Bottom
  - 4221. Cobble
  - 4222. Gravel
  - 4223. Sand
  - 4224. Mud
  - 4225. Organic
- 4230. Aquatic Bed
  - 4231. Algal

- 4232. Aquatic Moss
- 4233. Rooted Vascular
- 4234. Floating vascular
- 4240. Rocky Shore
  - 4241. Bedrock
  - 4242. Rubble
- 4250. Unconsolidated Shore
  - 4251. Cobble
  - 4252. Gravel
  - 4253. Sand
  - 4254. Mud
  - 4255. Organic
- 4260. Emergent Wetland
  - 4261. Nonpersistent

5000. Palustrine Habitats

- 5100. Perennial Water
  - 5110. Rock Bottom
    - 5111. Bedrock
    - 5112. Rubble
  - 5120. Unconsolidated Bottom
    - 5121. Cobble
    - 5122. Gravel
    - 5123. Sand
    - 5124. Mud
    - 5125. Organic
  - 5130. Aquatic Bed
    - 5131. Algal
    - 5132. Aquatic Moss
    - 5133. Rooted Vascular
    - 5134. Floating vascular
  - 5140. Emergent Wetland
    - 5141. Nonpersistent
- 5200. Intermittent or Saturated
  - 5210. Unconsolidated Shore
    - 5211. Cobble
    - 5212. Gravel
    - 5213. Sand
    - 5214. Mud
    - 5215. Organic
  - 5220. Moss-Lichen Wetland
    - 5221. Moss
    - 5222. Lichen
  - 5230. Emergent Wetland
    - 5231. Nonpersistent
    - 5232. Persistent
  - 5240. Scrub-Shrub Wetland

- 5241. BLD
- 5242. NLD
- 5243. BLE
- 5244. NLE
- 245. Dead
- 5250. Forested Wetland
  - 5251. BLD
  - 5252. NLD
  - 5253. BLE
  - 5254. NLE
  - 5255. Mixed
  - 5256. Dead

6000. Upland Habitats

- 6100. Supratidal Upland
  - 6110. Rocky Upland
    - 6111. Bedrock
    - 6112. Rubble
  - 6120. Unconsolidated Upland
    - 6121. Cobble
    - 6122. Gravel
    - 6123. Sand
    - 6124. Clay
    - 6125. Loam
    - 6126. Organic
  - 6130. Herbaceous Upland
    - 6131. Grassland
    - 6132. Broad-leaved Herbs
  - 6140. Scrub-Shrub Upland
    - 6141. BLD
    - 6142. NLD
    - 6143. BLE
    - 6144. NLE
    - 6145. Dead
  - 6150. Forested Upland
    - 6151. BLD
    - 6152. NLD
    - 6153. BLE
    - 6154. NLE
    - 6155. Mixed
    - 6156. Dead
- 6200. Inland Upland
  - 6210. Rocky Upland
    - 6211. Bedrock
    - 6212. Rubble
  - 6220. Unconsolidated Upland
    - 6221. Cobble

- 6222. Gravel
- 6223. Sand
- 6224. Clay
- 6225. Loam
- 6226. Organic
- 6230. Herbaceous Upland
  - 6231. Grassland
  - 6232. Broad-leaved Herbs
- 6240. Scrub-Shrub Upland
  - 6241. BLD
  - 6242. NLD
  - 6243. BLE
  - 6244. NLE
  - 6245. Dead
- 6250. Forested Upland
  - 6251. BLD
  - 6252. NLD
  - 6253. BLE
  - 6254. NLE
  - 6255. Mixed
  - 6256. Dead

7000. Perennial Snow and Ice Habitats
- 7100. Perennial Snowfields
- 7200. Glaciers

8000. Cultural Land Cover
- 8100. Developed Upland
  - 8110. Impervious Cover
    - 8111. Paved Lot
    - 8112. Paved Roadway
    - 8113. Large Building
    - 8114. Impervious Complex
  - 8120. Built-up Cover
    - 8121. Commercial or Service Complex
    - 8122. Industrial Complex
  - 8130. Residential Cover
    - 8131. Low Density
    - 8132. Medium Density
    - 8133. High Density
  - 8140. Rocky Cover
    - 8141. Rocky Revetment
    - 8142. Open Quarry
  - 8150. Unconsolidated Cover
    - 8151. Cleared Land
    - 8151. Dirt Lot
    - 8152. Gravel Road
    - 8153. Railway Corridor

- 8154. Mining Operation
- 8155. Landfill Operation
- 8160. Herbaceous Cover
  - 8161. Managed Turf
  - 8162. Managed Garden
  - 8163. Managed Old Field
- 8170. Shrub Cover
  - 8171. Managed Shrubs
- 8180. Tree Cover
  - 8181. Managed Trees

8200. Agricultural Upland
- 8210. Rocky Cover
  - 8211. Rocky Revetment
- 8220. Unconsolidated Cover
  - 8221. Unvegetated Farmland
- 8230. Herbaceous Cover
  - 8231. Turf
  - 8232. Pasture
  - 8233. Hay Meadow
  - 8234. Crops/Cover Crops
- 8240. Shrub Cover
  - 8241. Shrub Nursery
  - 8242. Shrub Rangeland
- 8250. Tree Cover
  - 8251. Tree Farm
  - 8252. Orchard
  - 8253. Wooded Rangeland

8300. Developed and Managed Wetlands and Water
- 8310. Impervious Cover
  - 8311. Impervious Bottom
  - 8312. Impervious In-water Structure
- 8320. Built-up Cover
  - 8321. Pervious In-water Structure
  - 8322. In-water Commercial or Service Complex
  - 8323. In-water Industrial Complex
  - 8324. Shellfish Aquiculture
  - 8325. Finfish Aquiculture
- 8330. Residential Cover
  - 8331. In-water Residential Complex
- 8340. Rocky Cover
  - 8341. Rocky Shoreline Structure
  - 8342. Rocky In-water Structure
- 8350. Unconsolidated Cover
  - 8351. Managed Unconsolidated Bottom
  - 8352. Managed Unconsolidated Shore
- 8360. Herbaceous Cover

- 8361. Managed Herbaceous Wetland
- 8362. Agricultural Herbaceous Wetland
- 8363. Grazed Herbaceous Wetland

8370. Shrub Cover

- 8371. Managed Wetland Shrubs
- 8372. Agricultural Wetland Shrubs
- 8373. Grazed Shrub Wetland

8380. Tree Cover

- 8381. Managed Wetland Trees
- 8382. Agricultural Wetland Trees
- 8383. Grazed Wooded Wetland

Appendix 5: NCNERR Species List

Appendix 5: NCNERR Species List

Group: Birds	
Common Name	**Scientific Name**
American avocet	*Recurvirostra americana*
American bittern	*Botaurus lentiginosus*
American black duck	*Anas rubripes*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American flycatcher	*Empldonaxs alvinii*
American goldenfinch	*Carduelis tristis*
American golden plover	*Pluvialis dominica*
American kestrel	*Falco sparverius*
American oystercatcher	*Haematopus palliates*
American pipit	*Anthus spinoletta*
American redstart	*Setophaga ruticilla*
Amercian robin	*Turdus migratorius*
American white pelican	*Pelecanus erythrorhynchos*
American wigeon	*Anas americana*
American woodcock	*Philohela minor*
Audubon's shearwater	*Puffinus iherminieri*
Bald eagle	*Haliaeetus leucocephalus*
Baltimore oriole	*Icterus galbula*
Bank swallow	*Riparia riparia*
Barn owl	*Tyto alba*
Barn swallow	*Hirundo rustica*
Bay breasted warbler	*Dendroica castanea*
Belted kingfisher	*Megaceryle alcyon*
Black rail	*Laterallus jamaicensis*
Black guilliemot	*Cepphus grylle*
Black scoter	*Melanitta nigra*
Black skimmer	*Rynchops niger*
Black tern	*Chlidonias niger*

Group: Birds	
Common Name	**Scientific Name**
Black vulture	*Coragyps atratus*
Black-and-white warbler	*Mniotilta varia*
Black-bellied plover	*Pluvialis squatarola*
Black-billed cuckoo	*Coccyzus erythropthalmus*
Black-crowned night heron	*Nycticorax nycticorax*
Blackburnian warbler	*Dendroica fusca*
Blackpoll warbler	*Dendroica striata*
Black legged kittiwake	*Rissa tridactyla*
Black-throated blue warbler	*Dendroica caerulescens*
Black-throated green warbler	*Dendroica virens*
Blue goose	*Chen cairulescns*
Blue grosbeak	*Guiraca caerulea*
Blue jay	*Cyanocitta cristata*
Blue-gray gnatcatcher	*Polioptila caerulea*
Blue-headed vireo	*Vireo solitarius*
Blue-winged teal	*Anas discors*
Blue-winged warbler	*Vermivora pinus*
Boat-tailed grackle	*Quiscalus major*
Bobolink	*Dolichonyx oryzivorus*
Bonaparte's gull	*Larus philadelphia*
Brant	*Branta bernicla*
Bridled tern	*Sterna anaethetus*
Broad-winged hawk	*Buteo platypterus*
Brown creeper	*Certhia americana*
Brown headed cowbird	*Molothrus ater*
Brown headed nuthatch	*Sitta pusilla*
Brown noddy	*Anous stolidus*
Brown pelican	*Pelecanus occidentalis*

Appendix 5: NCNERR Species List

Group: Birds	
Common Name	**Scientific Name**
Brown thrasher	*Toxostoma rufum*
Bufflehead	*Bucephala albeola*
Canada goose	*Branta canadensis*
Canadian warbler	*Wilsonia canadensis*
Canvasback	*Aythya valisineria*
Cape may warbler	*Dendroica tigrina*
Carolina chickadee	*Parus carolinensis*
Carolina wren	*Thryothorus ludovicianus*
Caspian tern	*Sterna caspia*
Cattle egret	*Bubulcus ibis*
Cedar waxwing	*Bombycilla cedrorum*
Chestnut-sided warbler	*Dendroica pensylvanica*
Chimney swift	*Chaitura pelagica*
Chipping sparrow	*Spizella passerina*
Chuck-will's-widow	*Caprimulgus carolinensis*
Clapper rail	*Rallus longirostris*
Clay-colored sparrow	*Spizella pallida*
Cliff swallow	*Petrochelidon pyrrhonota*
Common goldeneye	*Bucephala clangula*
Common eider	*Somateria mollissima*
Common grackle	*Quiscalus quiscula*
Common ground-dove	*Columbina passerina*
Common loon	*Gavial immer*
Common merganser	*Mergus merganser*
Common moorhen	*Gallinula chloropus*
Common nighthawk	*Chordeiles minor*
Common redpoll	*Carduelis flammea*
Common snipe	*Capella gallinago*
Common tern	*Sterna hirundo*
Common yellowthroat	*Geothlypis trichas*

Group: Birds	
Common Name	**Scientific Name**
Connecticul warbler	*Oporornis agilis*
Cooper's hawk	*Accipiter cooperii*
Cory's shearwater	*Puffinus diomedea*
Curlew sanpiper	*Calidris ferruginea*
Dark-eyed junco	*Junco hyemalis*
Dickcissel	*Spiza Americana*
Double-crested cormorant	*Phalacrocorax auritus*
Dovekie	*Alle alle*
Downy woodpecker	*Picoides pubescens*
Dunlin	*Calidris alpine*
Eared grebe	*Podiceps nigricollis*
Eastern bluebird	*Sialia sialis*
Eastern kingbird	*Tyrannus tyrannus*
Eastern meadowlark	*Sturnella magna*
Eastern phoebe	*Sayornis phoebe*
Eastern screech owl	*Otus asio*
Eastern towhee	*Pipilo erthrophthalmus*
Eastern wood-pewee	*Contupus virens*
Empidonax, spp	Empidonax, spp
Eurasian collared-dove	*Streptopelia decaocto*
European starling	*Sturnus vulgaris*
Evening grosbeak	*Hesperiphona vestertina*
Field sparrow	*Spizella pusilla*
Fish crow	*Corvus ossifragus*
Forster's tern	*Sterna forsteri*
Fox sparrow	*Passerella iliaca*
Franklin's gull	*Larus pipizcan*
Gadwall	*Anas strepera*
Glaucous gull	*Larus hyperboreus*
Glossy ibis	*Plegadis falcinellus*

Appendix 5: NCNERR Species List

Group: Birds	
Common Name	**Scientific Name**
Golden plover	*Pluvialis dominica*
Golden winged warbler	*Vermivora chrysopter*
Golden-crowned kinglet	*Regulus satrapa*
Grasshopper sparrow	*Ammodramus savannarum*
Gray catbird	*Dumetella carolinensis*
Gray kingbird	*Tyrannus dominicensis*
Gray-cheeked thrush	*Catharus minimus*
Great black-backed gull	*Larus marinus*
Great blue heron	*Ardea herodias*
Great cormorant	*Phalacrocorax carbo*
Great crested flycatcher	*Myiarchus crinitus*
Great egret	*Casmerodius albus*
Great horned owl	*Bubo virginianus*
Greater scaup	*Aythya marila*
Greater shearwater	*Puffinus gravis*
Greater yellowlegs	*Tringa melanoleuca*
Green heron	*Butorides striatus*
Green-winged teal	*Anas crecca*
Gull-billed tern	*Gelochelidon nilotica*
Harlequin duck	*Histrionicus histrionicus*
Hermit thrush	*Catharus guttatus*
Herring gull	*Larus argentatus*
Hooded merganser	*Lophodytes cucullatus*
Hooded warbler	*Wilsonia citrina*
Horned grebe	*Podiceps auritus*
Horned lark	*Eremophila alpestris*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
House wren	*Troglodytes aedon*
Hudsonian godwit	*Limosa haemastica*

Group: Birds	
Common Name	**Scientific Name**
Iceland gull	*Larus glaucoides*
Indigo bunting	*Passerina cyanea*
Kentucky warbler	*Oporornis aglis*
Killdeer	*Charadrius vociferous*
King eider	*Somateria spectabilis*
King rail	*Rallus elegans*
Lapland longspur	*Calcarius lapponicus*
Lark sparrow	*Chondestes grammacus*
Laughing gull	*Larus atricilla*
Least bittern	*Ixobrychus exilis*
Least flycatcher	*Empidonaz minimus*
Least sandpiper	*Calidris minutilla*
Least tern	*Sterna albifrons*
Lesser black-backed gull	*Larus fuscus*
Lesser scaup	*Aythya affinis*
Lesser yellowlegs	*Tringa flavipes*
Little blue heron	*Florida caerulea*
Little gull	*Larus minutus*
Lincoln's sparrow	*Melospiza lincolnii*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Long-billed dowitcher	*Limnodromus scolopaceus*
Long-tailed duck	*Clangula hyemalis*
Magnificent frigatebird	*Fregata magnificens*
Magnolia warbler	*Dendroica magnolia*
Mallard	*Anas platyrhynchos*
Marbled godwit	*Limosa fedoa*
Marsh wren	*Cistothorus palustris*
Masked booby	*Sula dactylatra*
Merlin	*Falco columbarius*

Appendix 5: NCNERR Species List

Group: Birds	
Common Name	**Scientific Name**
Mississippe kite	*Ictinia mississipiensis*
Mourning dove	*Zenaida macroura*
Mourning warbler	*Oporornis philadelphia*
Mute swan	*Cygnus olor*
Narshville warbler	*Vermivora ruficapilla*
Nelson's sharp-tailed	*Ammodramus nelsoni*
N. rough-winged swallow	*Stelgidopteryx ruficollis*
Northern bobwhite	*Colinus virginianus*
Northern cardinal	*Cardinalis cardinalis*
Northern flicker	*Colaptes auratus*
Northern gannet	*Morus bassanus*
Northern harrier	*Circus cyaneus*
Northern mockingbird	*Mimus polyglottos*
Northern parula	*Parula americana*
Northern pintail	*Anas acuta*
Northern saw-whet owl	*Aegolius acadicus*
Northern shoveler	*Anas clypeata*
Northern waterthrush	*Seiurus noveboracensis*
Oldsquaw	*Clangula hyemalis*
Orange-crowned warbler	*Vermivora celata*
Orchard oriole	*Icterus spurius*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapillus*
Painted bunting	*Passerina ciris*
Palm warbler	*Dendroica palmarum*
Parastic jaeger	*Stercorarius parasiticus*
Pectoral sandpiper	*Calidris melnotos*
Peregrine falcon	*Falco peregrinus*
Philadelphia vireo	*Vireo philadelphicus*
Pied-billed grebe	*Podilymbus podiceps*

Group: Birds	
Common Name	**Scientific Name**
Pileated woodpecker	*Dryocopus pileatus*
Pine siskin	*Carduelis pinus*
Pine warbler	*Dendroica pinus*
Piping plover	*Charadrius melodus*
Pomarine jaeger	*Stercorarius pomarinus*
Prairie warbler	*Dendroica discolor*
Prothonotary warbler	*Protonotaria citrea*
Purple finch	*Carpodacus purpureus*
Purple gallinule	*Porphurula martinica*
Purple martin	*Progne subis*
Purple sandpiper	*Calidris maritima*
Razorbill	*Alca torda*
Red knot	*Calidris canutus*
Red phalarope	*Phalaropus fulicarius*
Red-bellied woodpecker	*Melanerpes carolinus*
Red-breasted merganser	*Mergus serrator*
Red-breasted nuthatch	*Sitta canadensis*
Red-eyed vireo	*Vireo olivaceus*
Redhead	*Aythya americana*
Redish egret	*Dichromanassa rufescens*
Red-headed woodpecker	*Melanerpes erthrocehpalus*
Red-necked grebe	*Poduceps grisegena*
Red-necked phalarope	*Phalaropus fulicarius*
Red--shouldered hawk	*Buteo lineatus*
Red-winged blackbird	*Agelaius phoeniceus*
Red-tailed hawk	*Buteo jamaicensis*
Red-throated loon	*Gavia stellata*
Ring-billed gull	*Larus delawarensis*
Ring-necked duck	*Aythya collarus*
Rock dove	*Columba livia*

Appendix 5: NCNERR Species List

Group: Birds	
Common Name	**Scientific Name**
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Roseate spoonbill	*Ajaia ajaja*
Royal tern	*Sterna maxima*
Ruby-crowned kinglet	*Regulus calendula*
Ruby-throated hummingbird	*Archilochus colubris*
Ruddy duck	*Oxyura jamaicensis*
Ruddy turnstone	*Arenaria interpres*
Rufous-sided towhee	*Pipila erythrophthalmus*
Rusty blackbird	*Euphagus carolinus*
Saltmarsh sharp-tailed	*Ammodramus cauducutus*
Sanderling	*Calidris alba*
Sandwich tern	*Sterna sandvicensis*
Savannal sparrow	*Passerculus sandwichensis*
Scarlet tanger	*Piranga olivacea*
Seaside sparrow	*Ammospiza maritime*
Sedge wren	*Cistothorus platensis*
Semipalmated plover	*Charadrius semipalmatus*
Semipalmated sandpiper	*Calidris pusilla*
Sharp-shinned hawk	*Accipiter striatus*
Shiny cowbird	*Molothrus bonariensis*
Short-billed dowitcher	*Limnodromus griseus*
Short-eared owl	*Asio flammeus*
Snow bunting	*Plectrophenax nivalis*
Snow goose	*Chen caerulescens*
Snowy owl	*Nyctea scandiaca*
Snowy egret	*Egretta thula*
Solitary sandpiper	*Tringa solitaria*
Song sparrow	*Melospiza melodia*
Sora	*Porzana carolina*
Sooty shearwater	*Puffinus griseus*

Group: Birds	
Common Name	**Scientific Name**
Sooty tern	*Sterna fuscata*
Spotted sandpiper	*Actitis macularia*
Stilt sandpiper	*Micropalama himantopus*
Summer tanger	*Piranga rubra*
Surf scoter	*Melanitta perspicillata*
Swainson's thrush	*Catharus ustulatus*
Swallow-tailed kite	*Elanoides forficatus*
Swamp sparrow	*Melispiza georgiana*
Tennessee warbler	*Vermivora peregrina*
Thick-billed murre	*Uria lomvia*
Tree swallow	*Iridoprocne bicolor*
Tricolored heron	*Hydranassa tricolor*
Tufted titmouse	*Parus bicolor*
Tundra swan	*Cygnus columbianus*
Turkey vulture	*Cathartes aura*
Upland sandpiper	*Bartramia longicauda*
Veery	*Catharus fuscenscens*
Vesper sparrow	*Pooecetes gramineus*
Virginia rail	*Rallus limicola*
Western kingbird	*Tyrannus verticalis*
Western sandpiper	*Calidris mauri*
Whimbrel	*Numenius phaeopus*
Whip-poorwill	*Caprimulgus vociferus*
White ibis	*Eudocimus albus*
White-crowned sparrow	*Zonotrichia leucophrys*
White-eyed vireo	*Vireo griseus*
White-rumped sandpiper	*Calidris fuscicollis*
White-tailed kite	*Elanus leucurus*
White-throated sparrow	*Zonotrichia albicollis*
White-winged scoter	*Melanitta deglandi*

Appendix 5: NCNERR Species List

Group: Birds	
Common Name	**Scientific Name**
Willet	*Catoptrophorus semipalmatus*
Willow-alder flycatcher	*Empidonaz alnorum*
Wilson's thalarope	*Steganopus tricolor*
Wilson's plover	*Charadrius alexandrinus*
Wilson's storm-tetrel	*Oceanites oceanicus*
Wilson's warbler	*Wilsonia pusilla*
Winter wren	*Troglodytes troglodytes*
Wood duck	*Aix sponsa*
Wood thrush	*Hylocichla mustelina*
Worm-eating warlbler	*Helmitheros vermivorus*
Yellow-bellied flycatcher	*Empidonaz flaviventris*
Yellow-billed cuckoo	*Coccuzus americanus*
Yellow crowned night heron	*Nyctanassa violacea*
Yellow-headed blackbird	*Xanthocehalus xanthocephalus*
Yellow warbler	*Dendroica petechia*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Yellow-breasted chat	*Icteria virens*
Yellow-rumped warbler	*Dendroica coronata*
Yellow-throated vireo	*Vireo flavifrons*
Yellow-throated warbler	*Dendroica dominica*

Group: Mammals	
Common Name	**Scientific Name**
Feral horse	*Equus caballus*
Raccoon	*Procyon lotor*
Nutria	*Myocastor coypus*
Virginia opossum	*Didelphis virginiana*
Atlantic bottle-nose dolphin	*Tursiops truncatus*
Meadow mouse	*Microtus pennsylvanica*

Group: Mammals	
Common Name	**Scientific Name**
Cotton mouse	*Peromyscus gossypinus*
White-tailed deer	*Odocoileus virginianus*
River otter	*Lutra canadensis*
Marsh rabbit	*Sylvilagus palustris*
Eastern cottontail rabbit	*Sylvilagus floridanus*
Short-tailed shrew	*Blarina brevicauda*
Eastern mole	*Scalopus aquaticus*
Big brown bat	*Eptesicus fuscus*
Gray squirrel	*Sciurus carolinensis*
Fox squirrel	*Sciurus niger*
Muskrat	*Ondontra*
Red fox	*Vulpes vulpes*
Gray fox	*Urocyon cinereoargenteas*
Harbor seal	*Phoca vitulina*
Harbor porpoise	*Phocoena phocoena*
House mouse	*Mus musculus*
Norway rat	*Rattus norvegicus*
Mink	*Mustela vison*
Hispid cotton rat	*Sigmondon hispidus*
Marsh rice rat	*Oryzomys palustris*
Least shrew	*Cryptotis parva*
Red bat	*Lasiurus borealis*
Seminole bat	*Lasiurus seminolus*
Manatee	*Trichechus manatus*
Eastern harvest mouse	*Reithrodontomys humilis*
White-footed mouse	*Peromyscus leocopus*
Marsh rice rat	*Oryzomys palustris*
Norway rat	*Rattus norvegicus*
Least shrew	*Crytotis parva*
Southerneastern shrew	*Sorex longerosytris*

Appendix 5: NCNERR Species List

Group: Mammals	
Common Name	**Scientific Name**
Meadow vole	*Microtus pennsylvanicus*

Group: Reptiles	
Common Name	**Scientific Name**
Alligator	*Alligator mississippiensis*
Atlantic loggerhead	*Caretta caretta caretta*
Black rat snake	*Elaphe □olyploi obsoleta*
Bog turtle	*Clemmys muhlenbergii*
Broad-headed skink	*Eumeces laticeps*
Brown water snake	*Natrix taxispilota*
Carolina pygmy rattlesnake	*Sistrurus miliarius miliarius*
Carolina watersnake	*Nerodia sipedon williamengelsi*
Chicken turtle	*Deirochelys reticularia*
Coastal Plain milk snake	*Lampropeltis triangulum*
Common watersnake	*Nerodia sipedon sipedon*
Corn snake	*Elaphe guttata guttata*
Eastern box turtle	*Terrapeme □olyploi carolina*
Eastern coachwhip	*Masticophis flagellum flagellum*
Eastern cottonmouth	*Agkistrodon piscivorus*
Eastern diamond-backed tattlesnake	*Crotalus adamanteus*
Eastern garter snake	*Thamnophis sirtalis sirtalis*
Eastern glass lizard	*Ophisaurus ventralis*
Eastern hognose snake	*Heterdon platyrhinos*
Eastern king snake	*Lampropeltis getulus getulus*
Eastern milksnake	*L. triangulum triangulum*
Eastern mud snake	*Farancia abacura abacura*
Eastern mud turtle	*Kinosternon subrubrum subrubrum*
Eastern musk turtle stinkpot	*Sternotherus odoratus*
Eastern painted turtle	*Chrysemys picta picta*

Group: Reptiles	
Common Name	**Scientific Name**
Eastern ribbon snake	*Thamnophis sauritus sauritus*
Eastern smooth earth snake	*Virginia valeriae*
Eastern wood snake	*Carphophis amoenus amoenus*
Fence lizard	*Sceloporus □olyploid hyacinthinus*
Five-lined skink	*Eumeces fasciatus*
Florida cooter	*Chrysemys floridana floridana*
Green anole (Carolina anole)	*Anolis carolinensis*
Green sea turtle	*Chelonia mydas*
Ground skink	*Leiolopisma laterale*
Leatherback sea turtle	*Dermochelys coriacea*
Little brown skink	*Scincella lateralis*
Mimic glass lizard	*Ophisaurus mimicus*
Northern black racer	*Coluber constrictor constrictor*
Northern brown snake	*Storeria dekayi dekayi*
Northern diamondback terrapin	*malaclemys terrapin terrapin*
Northern scarlet snake	*Cemophora coccinea copei*
Nothern water snake	*Natrix sipedon sipedon*
Pine woods snake	*Rhadinae flavilata*
Rainbow snake	*Farancia erythrogram*
Red bellied cooter	*Pseudemys rubriventris*
Red-bellied snake	*Storeria occipitomaculata*
Red-bellied turtle	*Chrysemys rubiventris*
Red-bellied watersnake	*Nerodia erythrogaster erythrogaster*
Red-eared slider	*T. scripta elegans*
Rough earth snake	*Virginia striatulla*
Rough green snake	*Opheodrys aestivus*
Scarlet kingsnake	*Lampropeltis triangulum elapsoides*
Six-lines racerunner	*Cnemidophorus sexlineatus*
Slender glass lizard	*Ophisaures attenuatus*
Snapping turtle	*Chelydra serpentina*

Appendix 5: NCNERR Species List

Group: Reptiles	
Common Name	**Scientific Name**
Southeastern five-lined skink	*Eumeces inexpectatus*
Southern copperhead	*Agkistrodon contortrix*
Southern hog-nosed snake	*Heterodon simus*
Southern ringneck snake	*Diadophis punctatus punctatus*
Spotted turtle	*Clemmys guttata*
Timber rattlesnake	*Crotalus horridus*
Yellow bellied slider	*Trachemys scripta scripta*
Yellow ratsnake	*E. olyploi quadrivittata*
Yellow-bellied turtle	*Chrysemys scripta scripta*

Group: Amphibians	
Common Name	**Scientific Name**
Northern cricket frog	*Acris crepitans crepitans*
Southern cricket frog	*Acris gryllus gyrllus*
Mabee's salamander	*Ambystoma mabeei*
Spotted salamander	*Ambystoma muculatum*
Marbled salamander	*Ambystoma opacum*
Mole salamander	*Ambystoma talpoideum*
Eastern tiger salamander	*Ambystoma tigrinum tigrinum*
Two toed amphiuma	*Amphiuma means*
Green salamander	*Aneides aeneus*
Eastern olyploi toad	*Bufo americanus americanus*
Common toad	*Bufo bufo*
Oak toad	*Bufo quercicus*
Southern toad	*Bufo terrestris*
Fowlers toad	*Bufo woodhousei fowleri*
Southern dusky salamander	*Desmognathus auriculatus*
Spotted dusky salamander	*Desmognathus conanti*
Northern dusky salamander	*Desmognathus fuscus*

Group: Amphibians	
Common Name	**Scientific Name**
Eastern narrow-mouthed toad	*Gastrophryne carolinensis*
Four-toed salamander	*Hemidactylium scutatum*
Gray tree frog	*Hyla chrysoscelis (diploid form)*
Northern spring peeper	*Hyla cinera cinera*
Green treefrog	*Hyla cinerea*
Northern cricket frog	*Hyla crucifer crucifer*
Pine woods tree frog	*Hyla femoralis*
Green tree frog	*Hyla gratiosa*
Squirell tree frog	*Hyla squirella*
Gray tree frog	*Hyla versicolor (olyploidy form)*
Little grass frog	*Limnaoedus ocularis*
Broken-striped newt	*N. v. dorsalis*
Dwarf waterdog	*Necturus punctatus*
Red-spotted newt	*Notophthalmus viridescens viridescens*
Atlantic coastal slimy salamander	*Plethodon chlorobryonis*
Eastern red-backed salamander	*Plethodon cinereus*
Slimy salamander	*Plethodone glutinosus glutinous*
Northern spring peeper	*Pseudacris crucifer crucifer*
Brimley's chorus frog	*Pseudarcris brimleyi*
Upland chorus frog	*Pseudarcris trisertiata feriarum*
Eastern mud salamander	*Pseudotriton montanus montanus*
Bullfrog	*Rana catesbeiana*
Greed frog	*Rana clamitans melanota*
Pickerel frog	*Rana palustris*
Southern leopard frog	*Rana sphenocephala utricularia*
Wood frog	*Rana sylvatica*
Southern leopard frog	*Rana utricularia*
Carpenter frog	*Rana virgatipes*
Eastern spadefoot	*Scaphiopus holbrookii*
Greater siren	*Siren lacertina*

Appendix 5: NCNERR Species List

Group: Amphibians	
Common Name	**Scientific Name**
Many-lined salamander	*Stereochilus marginatus*

Group: Fish	
Common Name	**Scientific Name**
Abundant	*Serranus subligarius*
Alewife	*Alosa pseudorharengus*
American eel	*Anguilla rostrata*
American shad	*Alosa sapidissima*
Antenna codlet	*Bregmaceros atlanticus*
Atlantic bonito	*Sarda sarda*
Atlantic bumper	*Chloroscombrus chrysurus*
Atlantic croaker	*Micropogon undulatus*
Atlantic cutlassfish	*Trichiurus lepturus*
Atlantic menhaden	*Brevortia tyrannus*
Atlantic midshipman	*Porichthys plectrodon*
Atlantic needlefish	*Strongylura marina*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Atlantic silverside	*Menidia menidia*
Atlantic spadefish	*Chaetodipterus faber*
Atlantic stingray	*Dasyatis sabina*
Atlantic thread herring	*Opisthonema oglinum*
Banded amberjack	*Seriola zonata*
Banded drum	*Larimus fasciatus*
Banded killifish	*Fundulus diaphanus*
Bank cusk-eel	*Ophidion holbrookii*
Barbfish	*Scorpaena brasiliensis*
Bay anchovy	*Anchoa mitchilli*
Bay whiff	*Citharichthys spilopterus*
Belted sandfish	*Serranus subligarius*
Bighead searobin	*Prionothus tribulus*
Black bullhead	*Ictalurus melas*

Group: Fish	
Common Name	**Scientific Name**
Black crappie	*Pomoxis negromaculatus*
Black drum	*Pogonias cromis*
Black grouper	*Mycteroperca bonaci*
Black seabass	*Centropristis striata*
Blackcheek tonguefish	*Symphurus plagiusa*
Blue angelfish	*Holacanthus bermudensis*
Blue runner	*Caranx crysos*
Blue tang	*Acanthurus coeruleus*
Blueback herring	*Alosa aestivalis*
Blueback herring	*Enneacarthus gloriosus*
Bluefish	*Pomatomus saltatrix*
Bluegill	*Lepomis macrochirus*
Bluntnose stingray	*Dasyatis sayi*
Bowfin	*Amia calva*
Broad flounder	*Paralichthys squamilentus*
Brown bullhead	*Ictalurus nebulosis*
Butterfish	*Peprilus triacanthus*
Carolina hake	*Urophycis earlli*
Carp	*Cyprinus carpio*
Chain pickerel	*Esox niger*
Chain pipefish	*Syngnathus louisianae*
Channel catfish	*Ictalurus punctatus*
Clearnose skate	*Raja eglanteria*
Cocoa damselfish	*Stegastes variablilis*
Conger eel	*Conger oceanicus*
Cownose ray	*Rhinoptera bonasus*
Crested blenny	*Hypleurochilus geminatus*
Crevalle jack	*Caranz hippos*
Croaker	*Micropogon undulatus*
Cubbyu	*Pareques umbrosus*
Darter goby	*Gobionellus boleosoma*
Doctorfish	*Acanthurus chirurgus*
Dog snapper	*Lutjanus jocu*

Appendix 5: NCNERR Species List

Group: Fish	
Common Name	**Scientific Name**
Dusky damselfish	*Stegastes dorsopunicans*
Dusky pipefish	*Syngnathus floridae*
Emerald sleeper	*Erotelis smaragdus*
Feather blenny	*Hypsoblennius hentzi*
Flier	*Centrarchus marcopterus*
Florida pompano	*Trachinotus falcatus*
Flying gurnard	*Dactylopterus volitans*
Freshwater goby	*Gobionellus shufeldti*
Frillfin goby	*Bathygobius soporator*
Fringed filefish	*Monacanthus ciliatus*
Fringed flounder	*Etropus crossotus*
Gag	*Mycteroperca bonaci*
Gag	*Mycteroperca microlepis*
Gizzard shad	*Dorosoma cepedianum*
Golden shiner	*Notemigonus crysoleucas*
Gray snapper	*Lutjanus griseus*
Gray triggerfish	*Balistes capriscus*
Great barracuda	*Sphyraena barracuda*
Greater amberjack	*Seriola dumerilli*
Green goby	*Microgobius thalassinus*
Guaguanche	*Sphyraena guachancho*
Gulf flounder	*Paralichthys albigutta*
Gulf kingfish	*Menticirrhus littoralis*
Gulf pipefish	*Syngnathus scovelli*
Halfbeak	*Hyporhamphus unifasciatus*
Hardhead catfish	*Arius felis*
Harvestfish	*Peprilus alepidotus*
Hickory shad	*Alosa mediocris*
Highfin goby	*Gobionellus oceanicus*
Hogchoker	*Trinectes maculatus*
Horse-eyed jack	*Caranx latus*
Inland silverside	*Menidia beryllina*
Inshore lizardfish	*Synodus foetens*

Group: Fish	
Common Name	**Scientific Name**
Irish pompano	*Diapterus auratus*
King mackerel	*Scomberomorus maculatus*
Ladyfish	*Elops saurus*
Lake chubsucker	*Erimzon sucetta*
Lane snapper	*Lutjanus synagris*
Largemouth bass	*Micropterus salmoides*
Leopard searobin	*Prinotus scitulus*
Lined seahorse	*Hippocampus erectus*
Longnose gar	*Lepisosteus osseus*
Longspine porgy	*Stenotomus caprinus*
Lookdown	*Selene vomer*
Lyre goby	*Evorthodus lyricus*
Margintail conger	*Paraconger caudilimbatus*
Marsh killifish	*Fundulus confluentus*
Mosquitofish	*Gambusia affinis*
Mummichog	*Fundulus heteroclitus*
Mutton snapper	*Lutjanus analis*
Naked goby	*Gobiosoma bosc*
Northern kingfish	*Menticirrhus saxatillis*
Northern pipefish	*Syngnathus fuscus*
Northern puffer	*Sphoeroides maculatus*
Northern searobin	*Prionotus*
Northern sennet	*Sphyraena borealis*
Ocellated flounder	*Ancylopsetta quadrocellata*
Offshore tonguefish	*Symphurus civitatium*
Orange filefish	*Aluterus schoepfi*
Oyster toad	*Opsanus tau*
Oyster toadfish	*Opsanus tau*
Painted wrasse	*Halichoeres caudalis*
Palometa	*Trachinotus goodei*
Permit	*Trachinotus falcatus*
Pigfish	*Orthopristis chrysoptera*
Pinfish	*Lagodon rhomboides*

Appendix 5: NCNERR Species List

Group: Fish	
Common Name	**Scientific Name**
Planehead filefish	*Monacanthus hispidus*
Planespotted eel	*Ophichthus ocellatus*
Pumpkinseed fish	*Lepomis gibbosus*
Rainwater killifish	*Lucania parva*
Red drum	*Sciaenops ocellatus*
Red snapper	*Lutjanus campechanus*
Redfin pickerel	*Esox americans*
Rock seabass	*Centropristis philadelphica*
Rough scad	*Trachurus lathami*
Rough silverside	*Membras martinica*
Rough silverside	*Membras martinica*
Round scad	*Decapterus punctatus*
Round scad	*Decapterus punctatus*
Sand perch	*Diplectrum formosum*
Schoolmaster	*Lutjanus apodus*
Scrawled cowfish	*Acanthostracion quadricornis*
Scrawled filefish	*Aluterus scriptus*
Scup	*Stenotomus chrysops*
Seaboard goby	*Gobiosoma ginsburgi*
Seaweed blenny	*Blennius marmoreus*
Seaweed blenny	*Parablennius marmoreus*
Sergeant major	*Abudefduf saxatilis*
Sharksucker	*Echeneis naucrates*
Sharptail goby	*Gobionellus hastatus*
Sheepshead	*Archosargus probatocephalus*
Sheepshead minnow	*Cyprinodont variegatus*
Shrimp eel	*Ophichthus gomesi*
Silver jenny	*Eucinostomus gula*
Silver perch	*Bairdiella chrysura*
Silver seatrout	*Cynoscion nothus*
Silverstripe halfbeak	*Hyporhamphus meeki*
Skillletfish	*Gobiesox strumosus*
Slippery dick	*Halichoeres bivitttus*

Group: Fish	
Common Name	**Scientific Name**
Smooth butterfly ray	*Gymnura micrura*
Smooth dogfish	*Mustelus canis*
Smooth puffer	*Lagocephalus laevigatus*
Snowy grouper	*Epinephelus niveatus*
Southern flounder	*Paralichthys lethostigma*
Southern hake	*Urophucis floridana*
Southern kingfish	*Menticirrhus americanus*
Southern stargazer	*Astroscopus y-graecum*
Southern stingray	*Dasyatis americana*
Spanish mackerel	*Scomberomorus maculatus*
Speckled worm eel	*Myrophis punctatus*
Spiny dogfish	*Squalus acanthias*
Spot	*Leiostomus xanthurus*
Spotfin mojarra	*Eucinostomus argenteus*
Spottail pinfish	*Diplodus holbrooki*
Spotted bass	*Micropterus punctulatus*
Spotted butterflyfish	*Chaetodon ocellatus*
Spotted hake	*Urophycis regia*
Spotted scorpionfish	*Scorpaena plumieri*
Spotted seatrout	*Cynoscion nebulosus*
Spotted whiff	*Citharichthys macrops*
Star drum	*Stellifer lanceolatus*
Stiped bass	*Morone saxatilis*
Striped anchovy	*Anchoa hepsetus*
Striped bass	*Morone saxatilis*
Striped blenny	*Chasmodes basquianus*
Striped burrfish	*Chilomycterus schoepfi*
Striped killifish	*Fundulus majalis*
Striped mullet	*Mugil cephalus*
Striped searobin	*Prionotus evolans*
Summer flounder	*Paralichthys dentatus*
Tadpole madtom	*Noturus gyrinus*
Tautog	*Tautoga onitis*

Appendix 5: NCNERR Species List

Group: Fish	
Common Name	**Scientific Name**
Threadfin shad	*Dorosoma petenense*
Tidewater silverside	*Menidia beryllina*
Tomtate	*Haemulon aurolineatum*
Vermilion snapper	*Rhomboplites aurorubens*
Warmouth	*Lepomis gulosus*
Weakfish	*Cynoscion regalis*
White catfish	*Ictalurus catus*
White grunt	*Haemulon plumieri*
White mullet	*Mugil curema*
White perch	*Morone americana*
Whitebone porgy	*Calamus leucosteus*
Whitespotted soapfish	*Rypticus maculatus*
Windowpane	*Scophthalmus aquosus*
Yellow bullhead	*Ictalurus natalis*
Yellow jack	*Caranx bartholomaei*
Yellow perch	*Perca flavescens*

Group: Invertabrates	
Common Name	**Scientific Name**
Acorn worm	*Balanoglossus auranticus*
Alternate bittium	*Diastoma alternatum*
Alternate tellin	*Tellina alternata*
Amethyst gem clam	*Gemma gemma*
Antillean lima	*Lima pellucida*
Arrow shrimp	*Tozeuma carolinense*
Atlantic abra	*Abra aequalis*
Atlantic auger	*Terebra dislocata*
Atlantic jackknife clam	*Ensis directus*
Atlantic jingle	*Anomia simplex*
Atlantic moon snail	*Polinices duplicatus*

Group: Invertabrates	
Common Name	**Scientific Name**
Atlantic oyster drill	*Urosalpinx cinerea*
Atlantic ribbed mussel	*Modiolus demissus*
Atlantic slipper shell	*Credpidula fornicata*
Atlantic surf clam	*Spisula solidissima*
Atlantic wing oyster	*Pteria colymbus*
Baby's ear	*Sinum perspectivum*
Banded hermit crab	*Pagurus annulipes*
Banded tulip	*Fasciolaria hunteria*
Barnacles on crabs and *Limulus*	*Balanus amphitrite*
Barnacles on crabs and *Limulus*	*Chelonibia patula*
Bay scallop	*Argopecten irradians*
Beach hopper	*Orchestia platensis*
Beach hopper	*Talorchestia longicornis*
Big claw snapping shrimp	*Alpheus heterochaelis*
Black marsh crab	*Sesarma reticulata*
Blood ark	*Anadara ovalis*
Blood worm	*Glycera americana*
Blood worm	*Glycera dibranchiata*
Blue crab	*Callinectes sapidus*
Boring sponge	*Cliona celata*
Brackish water mud crab	*Rhithropanopeus harrisii*
Brief squid	*Lolliguncula brevis*
Brown grooved shrimp	*Penaeus aztecus*
Brown moss animal	*Bugula neritina*
Bryozoan on *Pinnixa chaetopterana*	*Triticella elongata*
Carolina marsh clam	*Polymesoda caroliniana*
Cayenne keyhole limpet	*Diodora cayenensis*
Channeled barrel-bubble	*Retusa canaliculata*

Appendix 5: NCNERR Species List

Group: Invertabrates	
Common Name	**Scientific Name**
Channeled whelk	*Busycon canaliculatum*
Clam worm	*Nereis pelagica*
Cloak anemone	*Calliactus polypus*
Common awning clam	*Solemya velum*
Common blue mussel	*Mytilus edulis*
Common eastern chiton	*Chaetopleura apiculata*
Common eastern nassa	*Nassarius vibex*
Common mud crab	*Panopeus herbstii*
Common prawn	*Palaemonetes vulgaris*
Common slipper shell	*Crepidula fornicata*
Common starfish	*Asterias forbesi*
Conquina	*Donax parvula*
Convex slipper shell	*Crepidula convexa*
Coquina	*Donax romeri protracta*
Crab in bivalve shells and *Chaetopterus* tubes	*Pinnotheres maculata*
Crab in *Chaetopterus* tubes	*Pinnixa chaetopterana*
Crab on the underside of sand dollar	*Dissodactylus mellitae*
Crested oyster	*Ostrea equestris*
Cross-barned venus	*Chione cancellata*
Cross-hatched lucine	*Divaricella quadrisulcata*
Daisy brittlestar	*Ophiopholis aculeata*
Disk dosinia	*Dosinia discus*
Dragonfly	*Erythrodiplax berenice*
Dwarf hermit crab	*Pagurus longicarpus*
Easter mud nassa	*Ilyanassa obsoleta*
Eastern oyster	*Crassostrea virginica*
Eastern paper bubble	*Haminoea salitaria*
Eel grass shrimp	*Hippolyte pleuracantha*

Group: Invertabrates	
Common Name	**Scientific Name**
Fallen angel wing	*Barnea truncata*
False angel wing	*Petricola pholadiformis*
Feather duster	*Hydroides dianthus*
Feather duster	*Sabella microphthalma*
Feather duster	*Sabellaria vulgaris*
Feather-duster	*Janua brasilensis*
Fern hydroid	*Pennaria tiarella*
Five-hole sand dollar	*Mellita fquinquiesperforata*
Flat clawed hermit crab	*Pagurus pollicaris*
Flatworms in gill books of *Limulus*	*Bdellura candida*
Florida rock shell	*Thais hemostoma floridana*
Friendly crab	*Sesarma cinerea*
Garlic sponge	*Lissodendoryx isodictyalis*
Ghost crab	*Ocypode quadrata*
Ghost shrimp	*Callianassa major*
Giant atlantic cockle	*Dinocardium robustum*
Giant atlantic murex	*Murex fulvescens*
Giant scale worm	*Polydontes lupina*
Giant swallotail	*Papilio cresphontes*
Goose barnacle on gills of *Callinectes*	*Octolasmis mulleri*
Gray pygmy venus	*Chione grus*
Great southern white butterfly	*Ascia monuste phileta*
Greedy dove shell	*Anachis avara*
Green beads	*Perophora viridis*
Green tubed worm	*Loimia viridis*
Gribble	*Limnoria tripunctata*
Hairy brittlestar	*Ophiothrix angulata*

Appendix 5: NCNERR Species List

Group: Invertabrates	
Common Name	**Scientific Name**
Hairy mud crab	*Pilumnus sayi*
Half smooth odostome	*Odostomia seminuda*
Heart urchin	*Moira atropos*
Hermit crab hydroid	*Hydractinia echinata*
Hermit crab sponge	*Xestospongia halichondroides*
High tide barnacle	*Chthamalus fragilis*
Hooked mussel	*Brachiodontes recurvis*
Horseshoe crab	*Limulus polyphemus*
Hydroid on hermit crabs	*Hydractinia echinata*
In *Chaetopterus* tubes	*Polyonyx gibbesi*
In dead tests of *Mellita*	*Thalassema mellita*
Ivory barnacle	*Balanus eburneus*
Jointed worm	*Clymenella mucosa*
Knobbed whelk	*Busycon carica*
Laboratory ribbon worm	*Cerebratulus lacteus*
Laboratory sea cucumber	*Thyone briareus*
Lady crab	*Ovalipes ocellatus*
Lamp shell	*Glottidia pyramidata*
Lancelot	*Branchiostoma caribbean*
Leathery sea squirt	*Styela plicata*
Lettered olive	*Oliva sayana*
Lightning whelk	*Busycon contrarium*
Long-finned squid	*Loligo pealii*
Lug worm	*Arenicola cristata*
Lunar dove shell	*Mitrella lunata*
Mahogany data mussel	*Lithophaga bisulcata*
Mantis shrimp	*Squilla empusa*
Marsh periwinkle	*Littornia irrorata*
Mole crab	*Emerita talpoidea*

Group: Invertabrates	
Common Name	**Scientific Name**
Mud fiddler	*Uca pugnax*
Mussel crab	*Pinnotheres maculatus*
Northern dwarf tellin	*Tellina agilis*
Northern quahog	*Mercenaria mercenaria*
Northern star coral	*Astrangia astreiformis*
Opal worm	*Arabbella iricolor*
Ornate worm	*Amphitrite ornata*
Oyster crab	*Pinnotheres ostreum*
Palamedes Swallowtail butterfly	*Papilio palamedes*
Parchment worm	*Chaetopterus variopedatus*
Pink hearted hydroid	*Tubularia crocea*
Pink sea pork	*Amaroecium pellucidum*
Plumed worm	*Diopatra cuprea*
Plumed worm	*Onuphis magna*
Pollution worm	*Capitella capitata*
Porcelain crab	*Polyonyx gibbesi*
Porcelain crab	*Petrolistes galathinus*
Purple sea urchin	*Arbacia punctulata*
Purple striped barnacle	*Balanus amphitrite*
Purple tube sponge	*Adocia tubifera*
Purplish tagelus	*Tagelus divisus*
Red beard sponge	*Microciona prolifera*
Red-jointed fiddler	*Uca minax*
Rigid pen shell	*Atrina rigida*
Rock anemone	*aiptasis pallida*
Saltmarsh Skipper	*Panoquina panoquin*
Sand dollar crab	*Dissodoctylus mellitae*
Sand dollar sausage worm	*Thalassema mellita*
Sand fiddler	*Uca pugilator*

Appendix 5: NCNERR Species List

Group: Invertabrates	
Common Name	**Scientific Name**
Saw-tooth pen shell	*Atrina serrata*
Scale worm	*Lepidametria commensalis*
Scale worm	*Lepidonotus variablils*
Schorched mussel	*Brachiodontes exustus*
Sculptured top shell	*Calliostoma euglyptum*
Sea grape	*Mogula manhattensis*
Sea hare	*Aplysia willcoxi*
Sea mat	*Membranipora tenuis*
Sea nettle	*Chrysaora quinquecirrha*
Sea pork	*Amaroecium constellatum*
Sea roach	*Lygida exotica*
Sea spider	*Anoplodactylus lentus*
Sea walnut	*Mnemiopsis leidyi*
Sea whip	*Leptogorgia virgulata*
Sea whip barnacle	*Balanus galeatus*
Sheeps wool	*Amathia convoluta*
Shipworm	*Bankia gouldii*
Shipworm	*Teredo navalis*
Short-spined sea urchin	*Lytechinus variegatus*
Single-toothed simnia	*Neosimnia uniplicata*
Slipper shells on *Limulus*	*Crepidula fornicata*
Slipper shells on *Limulus* and hermit crab shells	*Crepidula plana*
Sloppy guts anemone	*Ceriantheopsis americanus*
Smooth barnacle	*Balanus improvisus*
Soft-shell clam	*Mya arenaria*
Southern quahog	*Mercenaria campechiensis*
Speckled crab	*Arenaeus cribrarius*
Spider crab	*Libinia dubia*
Spider crab	*Pelia mutica*

Group: Invertabrates	
Common Name	**Scientific Name**
Spotted shrimp	*Penaeus duorarum*
Staghorn bryozoan	*Schizoporella unicornis*
Stone crab	*Menippe mercenaria*
Stout tagelus	*Tagelus plebeius*
Striped hermit crab	*Clibanarius vittatus*
Striped sea cucumber	*Thyone gemmata*
Sulphur sponge	*Aplysilla sulfurea*
Sun sponge	*Hymeniacidon heliophila*
Sunray venus	*Macrocallista nimbosa*
Tenta macoma	*Macoma tenta*
Thick-lipped drill	*Eupleura caudata*
Tinted cantharus	*Cantharus tinctus*
Transparent shrimp	*Periclimenes longicaudatus*
Transverse ark	*Anadara transversa*
Tree coral	*Oculina arbuscula*
Trumpet worm	*Cistenides gouldii*
Tulip mussel	*Modiolus americanus*
Variable bittium	*Diastoma varium*
Variable olivella	*Olivella mutica*
Variable olivella	*Olivella mutica*
Virginia bittium	*Diastoma virginicum*
War-legs brittlestar	*Ophioderma brevispina*
Waterboatman	*Trichocorixa verticalis*
Wedge-shaped martesia	*Martesia cuneiformis*
White bearded ark	*Barbatia candida*
White sea pork	*Didemnum candidum*
White shrimp	*Penaeus setiferus*
White slipper shell	*Crepidula plana*
Worm sea cucumber	*Leptosynapta inhaerens*

Appendix 5: NCNERR Species List

Group: Plants and Ferns	
Common Name	**Scientific Name**
American beach grass	*Ammophila breviligulata*
American beauty berry	*Callicarpa americana*
American elderberry	*Sambucus canadensis*
American holly	*Ilex opaca*
Arrowhead, awl-leaf	*Sagittaria subulata*
Arrowhead, bulltongue	*Sagittaria falcata*
Asparagus	*Asparagus sp.*
Aster, slender	*Aster tenuifolius*
Bacopa	*Bacopa monnieri*
Bamboo-vine	*Smilax laurifolia*
Beach heath	*Hudsonia tomentosa*
Beach primrose	*Oenothera humifusa*
Beakrush, clustered	*Rhynchospora glomerata*
Beakrush, loosehead	*Rhynchospora chalorocephala*
Bean, wild	*Strophostyles helvola*
Bedstraw, catchweed	*Galium aparine*
Bee-balm	*Monarda punctata*
Beggarticks, smooth	*Bidens laevis*
Bermuda grass	*Cynodon dactylon*
Big cordgrass	*Spartina cynosuroides*
Bitter panicum	*Panicum amarum*
Black cherry	*Prunus serotina*
Black locust	*Robinia pseudo-acacia*
Black medicago	*Lythrum lineare*
Black needle rush	*Juncus roemerianus*
Black needlerush	*Juncos roemerianus*
Black willow	*Salix nigra*
Blackberry, sand	*Rubus cuneifolius*
Blackberry, serrate'leaf	*Rubus argutus*
Blanket flower	*Gallium hispidulum*
Blueberry, black highbush	*Vaccinium atrococcum*
Blueberry, elliott's	*Vaccinium elliotti*
Blue-eyed grass	*Sisyrinchium mucronatum*

Group: Plants and Ferns	
Common Name	**Scientific Name**
Bluegrass, annual	*Poa annua*
Bluestem, little	*Schizachyrium scoparium*
Broomsedge	*Andropogon virginicus*
Buckthorn	*Bumelia lycioides*
Bulrush	*Scirpus robustus*
Bulrush, softstem	*Scirpus validus*
Buttercup	*Ranunculus sp.*
Buttercup, celery-leaf	*Ranunculus sceleratus*
Cactus	*Opuntia compressa*
Camphor weed	*Pluchea purpurascens*
Camphorweed	*Gaillardia pulchella*
Carolina willow	*Salix caroliniana*
Cattail, common	*Typha latifolia*
Cattail, narrow-leaf	*Typha angustifolia*
Cattail, southern	*Typha domingensis*
Cherry, ground	*Physalis visocosa ssp. Maritima*
Chicksaw plum	*Prunus angustifolia*
Chickweed, mouse-ear	*Cerastium vicosum*
Climbing hempweed	*Mikania scandens*
Climbing milkweed	*Cynanchum palustre*
Clover	*Trifolium repens*
Coastal Plain willow, Ward's, swamp	*Salix caroliniana*
Cocklebur	*Xanthium strumarium*
Common reed	*Phragmites communis*
Coral honeysuckle	*Lonicera sempervirens*
Cranesbill, carolina	*Geranium carolinianum*
Creeping cucumber marsh	*Melothria pendula*
Cress, bitter	*Cardamine hairsuta*
Croton	*Croton punctatus*
Cucumber, creeping	*Melothria pendula*
Cudweed, narrow-leaf	*Gnaphalium purpureum var. falcatum*
Cutgrass, rice	*Leersia oryzoides*

Appendix 5: NCNERR Species List

Group: Plants and Ferns	
Common Name	**Scientific Name**
Daisy fleabane	*Erigeron canadensis*
Daisy, false	*Eclipta alba*
Dandelion, dwarf	*Krigia virginica*
Dayflower	*Commelina erecta*
Deertongue	*Dichanthelium clandestinum*
Dewberry	*Rubus trivialis*
Diodia	*Diodia teres*
Dock, water	*Rumex verticillatus*
Dodder	*Suscuta campestris*
Dog fennel	*Eupatorium capillifolium*
Dropwort, water	*Oxypolis rigidior*
Duckweed, greater	*Spirodela polythiza*
Duckweed, minute	*Lemna perpusilla*
Dwarf palmetto	*Sabal minor*
Ebony spleenwort	*Asplenium platyneuron*
Eelgrass	*Zostera marina*
Eelgrass	*Vallisneria americana*
Elephant's foot	*Elephantopus nudatus*
Evening primrose	*Oenothera laciniata*
Feather, parrot	*Myriophyllum brasiliense*
Fescue	*Festuca myuros*
Fetterbush, swamp	*Leucothoe racemosa*
Fimbry, forked	*Fimbristylis dichotoma*
Flatsedge, slender	*Cyperus fillicinus*
Flowering dogwood	*Cornus florida*
Foxtail grass	*Setaria geniculata*
Glasswort	*Salicornia virginica*
Goldenrod, anisescented	*Solidago odora*
Goldentop, slender	*Euthamia tenuifolia*
Grape, pigeon	*Vitis cinerea var. floridana*
Grass, □merican cupscale	*Sacciolepis striata*
Grasswort, carolina	*Lilaeopsis carolinensis*
Grasswort, eastern	*Lilaeopsis chinensis*

Group: Plants and Ferns	
Common Name	**Scientific Name**
Greenbriar, catbriar	*Smilax auriculata*
Greenbrier, cat	*Smilax gluca*
Greenbrier, catrier	*Smilax bona-nox*
Greenbrier, laurel-leaf	*Smilax laurifolia*
Greenvriar, catbriar	*Smilax rotundifolia*
Ground cherry	*Physalia viscose*
Groundsel tree, cotton bush, silverling	*Baccharis halimifolia*
Grounsel, wooly	*Senecio tomentosus*
Harper's sea rocket	*Cakile harperi*
Hedge bindweed	*Calystegia sepium*
Hemlock, poison	*Cicuta maculata*
Hempweed, climbing	*Mikania scandens*
Hercules club, devil's walking stick	*Aralia spinosa*
Hercules's club, toothache tree	*Xanthoxylum clava-herculis*
Honeysuckle, coral	*Lonicera sempervirens*
Horehound, water	*Lycopus virginicus*
Horseweed	*Erigeron Canadensis*
Hyssop, water	*Bacopa monnieri*
Jessamine, yellow	*Gelsemium sempervirens*
Lamb's quarters	*Chenopodium album*
Laurel oak	*Quercus laurifolia*
Lippia	*Limonium nashii*
Little blue stem	*Andropogon scoparius*
Live oak	*Quercus virginiana*
Lobelia, downy	*Lobelia puberula*
Loblolly pine	*Pinus taeda*
Loosestrife	*Lippia nodiflora*
Loosestrife, false	*Ludwigia alternifolia*
Low hop clover	*Trifolium campestre*
Maidencane	*Panicum hemitomom*

Appendix 5: NCNERR Species List

Group: Plants and Ferns	
Common Name	**Scientific Name**
Mallow, seashore	*Kosteletzkya virginica*
Marsh aster	*Aster tenuifolius*
Marsh elder	*Iva frutescens*
Marsh elder	*Iva imbricata*
Marsh fleabane	*Pluchea foetida*
Marsh gerardia	*Agalinis maritime*
Marsh pink	*Sabatia stellaris*
Marsh sedge	*Fibristylis spadicea*
Mascadine grape	*Vitis rotundifolia*
Mexican tea	*Chenopodium ambrosioides*
Milfoil, water	*Myriophyllum exalbescens*
Milfoil, yarrow	*Achillea millifolium*
Monarda, dotted	*Monarda punctata*
Morning glory	*Ipomoea sagittata*
Mudeflower, shade	*Micranthemum umbrosum*
Mudwort, awl-leaf	*Limosella subulata*
Muscadine grape	*Vitis rotundifolia*
Nightshade	*Solanum gracile*
Northern bayberry	*Myrica pensylvanica*
Orach	*Atriplex patula*
Orangegrass	*Hypericum gentianoides*
Panic grass	*Panicum virgatum*
Panicum, fall	*Panicum dichotomiflorum*
Paronychia	*Paroychia riparia*
Partridge pea	*Cassia fasciculare*
Passionflower	*Passiflora lutea*
Pearlwort, trailing	*Sagina decumbens*
Pennywort	*Heterotheca subaxillaris*
Pennywort, false	*Centella asiatica*
Pennywort, floating	*Hydrocotyle ranunculoides*
Pennywort, many-flower	*Hydrocotyle umbellata*
Peppervine	*Ampelopsis arboretum*
Persimmon	*Diospryos virginiana*

Group: Plants and Ferns	
Common Name	**Scientific Name**
Pickerelweed	*Pontederia cordata*
Pigweed	*Amaranthus pumilus*
Pimpernel, water	*Samolus parviflorus*
Pinweed, hairy	*Lechea mucrontha*
Pinweed, Leggett's	*Lechea pulchella*
Pittosporum	*Pittosporum tobira*
Plantain	*Plantago aristata*
Plantain	*Plantago lanceolata*
Plantain, pale seed	*Plantago virginica*
Plumegrass, sugarcane	*Saccharum giganteum*
Poison ivy	*Rus radicans*
Poke	*Phytolacca Americana*
Pondweed, bushy	*Najas flexilis*
Pondweed, clasping-leaf	*Potamogeton perfoliatus*
Pondweed, horned	*Zannichellia palustris*
Pondweed, leafy	*Potamogeton foliosus*
Pondweed, sago	*Potamogeton pectinatus*
Pondweeds	*Najas spp.*
Poor man's pepper	*Lactuca sp.*
Prickly pear cactus	*Opuntia drummondii*
Primrose, evening	*Oenothera humifusa*
Primrose, evening	*Oenothera laciniata*
Privet	*Ligustrum japonicum*
Purple muhly	*Muhlenbergia capillaries*
Purslane, water	*Ludwigia palustris*
Rabbit tobacco	*Gnaphalium obtusifolium*
Ragweed	*Ambrosia artemisiifolia*
Red bay	*Persea borbonia*
Red cedar	*Juniperus virginiana*
Redstem, pink	*Ammania teres*
Rush, leathery	*Juncus coriaceus*
Rush, soft	*Juncus effusus*
Rush, turnflower	*Juncus biflorus*

Appendix 5: NCNERR Species List

Group: Plants and Ferns	
Common Name	**Scientific Name**
Russian thistle	*Salsola kali*
Rye grass	*Elmus virginicus*
Salad, corn	*Valerianella radiata*
Salt cedar, tamarix	*Tamarix gallica*
Salt grass, spike	*Distichlis spicata*
Salt marsh cordgrass	*Spartina alterniflora*
Salt meadow hay	*Spartina patens*
Sand nettle	*Cnidoscolus stimulosus*
Sandmat, seaside	*Chamaesyce polygonifolia*
Sandspur	*Cenchrus tribuloides*
Sawgrass	*Cladium jamaicense*
Sea beach orach	*Atriplex arenaria*
Sea bean, beach pea	*Strophostyles helvola*
Sea blite	*Suaeda linearis*
Sea lavender	*Lepidium virginicum*
Sea lavender	*Limonium carolinianum*
Sea oats	*Uniola paniculata*
Sea ox-eye	*Borrichia frutescens*
Sea pink	*Sabatia stellaris*
Sea purslane	*Portulaca oleracea*
Sea purslane	*Sesuvium portulacastrum*
Sea rocket	*Cakile edentula*
Sea spurge	*Euphorbia polygonifolia*
Seashore mallow	*Kosteletskya virginica*
Seaside elder	*Iva imbricate*
Seaside goldenrod	*Solidago sempervirens*
Sedge, japanese	*Carex kobomugi*
Shadbush, serviceberry	*Amelanchier candensis*
Sheep sorrel	*Rumex acetosella*
Smartweed, dotted	*Polygonum punctatum*
Sorrel, sheep	*Rumex hastatulus*
Sourgrass	*Oxalis dillenii*

Group: Plants and Ferns	
Common Name	**Scientific Name**
Spanish bayonet	*Yucca aloifolia*
Spanish moss	*Tillandsia usneoides*
Spike rush	*Eleocharis parvula*
Spikerush, blunt	*Eleocharis obtusa*
Spikerush, small-fruit	*Elocharis microcarpa*
Spikerush, yellow	*Eleocharis flavescens*
Spring lady's tresses	*Spiranthes vernalis*
Squaw huckleberry	*Vaccinium stamineum*
St. Andrews cross	*Hypericum stragalum*
St. John's wort	*Hypericum hypericoides*
Starwort, water	*Callitriche heterophylla*
Sumac, winged	*Rhus copallina*
Swamp rose	*Rosa palustris*
Swamp tupelo	*Nyssa sylvatica var. biflora*
Sweet bay	*Magnolia virginiana*
Sweet white clover	*Medicago lupulina*
Sweet white clover	*Melilotus alba*
Sweetgum	*Liquidambar styraciflua*
Switchgrass	*Panicum virgatum*
Tea, mexican	*Chenopodium ambrosioides*
Thistle, russian	*Salsola kali*
Thistle, yellow	*Cirsium horridulum*
Thoroughwort	*Eupatorium pilosum*
Threesquare, common	*Scirpus americanus*
Threesquare, olney	*Scirpus olneyi*
Toadflax	*Linaria canadensis*
Toothache tree	*Zanthoxylum clava-herculis*
Tresses, ladies	*Spiranthes vernalis*
Vine, pepper	*Ampelopsis arborea*
Violet, bog white	*Viola lanceolata*
Virginia creeper	*Parthenocissus quinquefolia*
Water oak	*Quercus nigra*
Water pimpernel	*Samolus parviflorus*

Appendix 5: NCNERR Species List

Group: Plants and Ferns	
Common Name	**Scientific Name**
Watercress	*Nasturtium officinale*
Wax myrtle	*Myrica cerifera*
Weed, mermaid	*Proserpinaca palustris*
White mulberry	*Morus alba*
Widgeon grass	*Ruppis maritime*
Wild lettuce	*Hydrocotyle bonariensis*
Wild olive	*Osmanthus americana*
Wild sensitive plant	*Cassia nictitans*
Winged sumac	*Rhus copallina*
Wintergreen, spotted	*Chimaphila maculata*
Yarrow, common	*Achillea millefolium*
Yaupon	*Ilex vomitoria*
Yellow jessamine	*Gelsemium sempervirens*
Yellow-eyed grass	*Xyris difformis*
Yellow-eyed grass	*Xyris jupicai*
Yucca	*Yucca gloriosa*

Appendix 6: Bibliography of Research Conducted in NCNERR

Appendix 6: Bibliography of research conducted in NCNERR

Originally compiled by Lancaster et al. 1999. Additional references have been added since then by NCNERR staff.

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