Defense Coastal/Estuarine Research Program (DCERP)

Research Plan: Addendum I

August 15, 2008
For the period 2006 through 2011

Prepared for:
Strategic Environmental Research and Development Program (SERDP)

Prepared by:
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* RTI International is a trade name of Research Triangle Institute.
Views, opinions, and/or findings contained in the report are those of the authors and should not be construed as an official Department of Defense position or decision unless so designated by other official documentation.
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<tr>
<td>2-D</td>
<td>two-dimensional</td>
</tr>
<tr>
<td>3-D</td>
<td>three-dimensional</td>
</tr>
<tr>
<td>ADCIRC</td>
<td>Advanced Circulation (Model)</td>
</tr>
<tr>
<td>ADCP</td>
<td>Acoustic Doppler Current Profiler</td>
</tr>
<tr>
<td>ALPHA</td>
<td>Adapted Low-cost Passive High Absorption</td>
</tr>
<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
</tr>
<tr>
<td>AOC</td>
<td>areas of concern</td>
</tr>
<tr>
<td>ASCP</td>
<td>stomatal compensation point</td>
</tr>
<tr>
<td>AVIRIS</td>
<td>Sea-viewing Wide Field-of-view Sensor</td>
</tr>
<tr>
<td>AVP</td>
<td>autonomous vertical profiler</td>
</tr>
<tr>
<td>AWAC</td>
<td>Acoustic Wave and Current</td>
</tr>
<tr>
<td>BBN</td>
<td>Bayesian Belief Network</td>
</tr>
<tr>
<td>BLH</td>
<td>boundary layer height</td>
</tr>
<tr>
<td>BMA</td>
<td>benthic microalgae</td>
</tr>
<tr>
<td>BMP</td>
<td>best management practice</td>
</tr>
<tr>
<td>C</td>
<td>carbon</td>
</tr>
<tr>
<td>CAA</td>
<td>Clean Air Act</td>
</tr>
<tr>
<td>CAFO</td>
<td>confined animal feeding operation</td>
</tr>
<tr>
<td>CDOM</td>
<td>colored dissolved organic matter</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>CMS</td>
<td>Center for Marine Sciences</td>
</tr>
<tr>
<td>CO</td>
<td>carbon monoxide</td>
</tr>
<tr>
<td>CWA</td>
<td>Clean Water Act</td>
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<tr>
<td>CWSMB</td>
<td>Coupled Water and Salt Mass Balance</td>
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<td>DCERP</td>
<td>Defense Coastal/Estuarine Research Program</td>
</tr>
<tr>
<td>DEM</td>
<td>digital elevations model</td>
</tr>
<tr>
<td>DIC</td>
<td>dissolved inorganic carbon</td>
</tr>
<tr>
<td>DIN</td>
<td>dissolved inorganic nitrogen</td>
</tr>
<tr>
<td>DIP</td>
<td>dissolved inorganic phosphorus</td>
</tr>
<tr>
<td>DO</td>
<td>dissolved oxygen</td>
</tr>
<tr>
<td>DOC</td>
<td>dissolved organic carbon</td>
</tr>
<tr>
<td>DoD</td>
<td>U.S. Department of Defense</td>
</tr>
<tr>
<td>DOE</td>
<td>U.S. Department of Energy</td>
</tr>
<tr>
<td>DON</td>
<td>dissolved organic nitrogen</td>
</tr>
<tr>
<td>EF</td>
<td>emission factor</td>
</tr>
<tr>
<td>EOS</td>
<td>end of the season</td>
</tr>
<tr>
<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
</tr>
<tr>
<td>ESA</td>
<td>Endangered Species Act</td>
</tr>
<tr>
<td>ESM</td>
<td>Estuarine Simulation Model</td>
</tr>
<tr>
<td>FAC</td>
<td>fractional aerosol coefficients</td>
</tr>
<tr>
<td>FIB</td>
<td>fecal indicator bacteria</td>
</tr>
<tr>
<td>GIS</td>
<td>geographic information systems</td>
</tr>
<tr>
<td>GPS</td>
<td>global positioning system</td>
</tr>
<tr>
<td>HAB</td>
<td>harmful algal bloom</td>
</tr>
<tr>
<td>HPLC</td>
<td>high performance liquid chromatography</td>
</tr>
<tr>
<td>HSPF</td>
<td>Hydrologic Simulation Program Fortran</td>
</tr>
<tr>
<td>ICW</td>
<td>Intracoastal Waterway</td>
</tr>
<tr>
<td>INRMP</td>
<td>Integrated Natural Resources Management Plan</td>
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IPCC Intergovernmental Panel on Climate Change
IRM isotope ratio mass spectrometry
KBDI Keetch-Byram drought index
LCAC landing craft air cushion
LIDAR Light Detection and Ranging
LTSC Long-Term Shoreline Change
LVORI low visibility occurrence risk index
MA microalgal
MARDIS Monitoring and Research Data Information System
MARIS medium-spectral resolution, imaging spectrometer
MCASN Marine Corps Air Station New River
MCBCL Marine Corps Base Camp Lejeune
MCE modified combustion efficiency
MDN Mercury Deposition Network
MEM2 marsh equilibrium model 2
MHW mean high water
MODIS Moderate Resolution Imaging Spectroradiometer
MOU Memorandum of Understanding
N nitrogen
NAAQS National Ambient Air Quality Standards
NADP National Atmospheric Deposition Program
NCDCM North Carolina Division of Coastal Management
NCSU North Carolina State University
NAVFAC ESC Naval Facilities Engineering Service Center
NH3 ammonia
NLM nutrient load model
NO2 nitrogen dioxide
NOx nitrogen oxides
NOAA National Oceanic and Atmospheric Administration
NPP net primary production
NRE New River Estuary
NRESE New River Estuary Shoreline Erosion
NWS National Weather Service
O2 oxygen
O3 ozone
OC organic carbon
OPTMOD bio-optical model
OSC On-site Coordinator
P phosphorus
PAR photosynthetically active radiation
Pb lead
PB prescribed burning
PCR polymerase chain reaction
PI Principal Investigator
PM Program Manager, particulate matter
PM2.5, PMfine (fine) particulate matter with aerodynamic diameter smaller 2.5 microns
PM10 particulate matter with aerodynamic diameter smaller 10 microns
PM10-2.5, PMc (coarse) particulate matter aerodynamic diameter with between 2.5 and 10 microns
POC phase organic compound
QA quality assurance
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>QC</td>
<td>quality control</td>
</tr>
<tr>
<td>QPCR</td>
<td>quantitative polymerase chain reaction</td>
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<tr>
<td>RCC</td>
<td>Regional Coordinating Committee</td>
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<tr>
<td>RCW</td>
<td>red-cockaded woodpecker</td>
</tr>
<tr>
<td>RDBMS</td>
<td>Relational Database Management System</td>
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<tr>
<td>RFMSS</td>
<td>Range Facility Management Support System</td>
</tr>
<tr>
<td>RTI</td>
<td>RTI International</td>
</tr>
<tr>
<td>RTK</td>
<td>real-time kinematic</td>
</tr>
<tr>
<td>RWE</td>
<td>Representative Wave Energy</td>
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<tr>
<td>SAV</td>
<td>submerged aquatic vegetation</td>
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<td>SDI</td>
<td>smoke dispersion index</td>
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<tr>
<td>SeaWIFs</td>
<td>Sea-viewing Wide Field-of-view Sensor</td>
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<tr>
<td>SERDP</td>
<td>Strategic Environmental Research and Development Program</td>
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<tr>
<td>SET</td>
<td>surface elevation table</td>
</tr>
<tr>
<td>SMP</td>
<td>Smoke Management Plan</td>
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<tr>
<td>SO$_2$</td>
<td>sulfur dioxide</td>
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<tr>
<td>SOA</td>
<td>secondary organic aerosol</td>
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<tr>
<td>SOP</td>
<td>standard operating procedure</td>
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<td>SPARROW</td>
<td>Spatially Referenced Regressions On Watershed Attributes</td>
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<td>SSA</td>
<td>sea salt aerosol</td>
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<td>STEBR</td>
<td>Short-Term, Event Beach Response Model</td>
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<td>SWAN</td>
<td>Simulating Waves Nearshore (model)</td>
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<td>TAC</td>
<td>Technical Advisory Committee</td>
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<tr>
<td>TBD</td>
<td>to be determined</td>
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<tr>
<td>TLZ</td>
<td>Tactical Landing Zone</td>
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<tr>
<td>TMDL</td>
<td>total maximum daily load</td>
</tr>
<tr>
<td>TSS</td>
<td>total suspended solids</td>
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<tr>
<td>UNC-CH</td>
<td>University of North Carolina at Chapel Hill</td>
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<td>UNC-IMS</td>
<td>University of North Carolina Institute of Marine Sciences</td>
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<td>UNC-W</td>
<td>University of North Carolina at Wilmington</td>
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<td>USACE</td>
<td>U.S. Army Corps of Engineers</td>
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<td>USC</td>
<td>University of South Carolina</td>
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<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<td>USGS</td>
<td>U.S. Geological Survey</td>
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<td>VCIS</td>
<td>Ventilation Climate Information System</td>
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<td>VI</td>
<td>ventilation index</td>
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<td>VIMS</td>
<td>Virginia Institute of Marine Sciences</td>
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<td>VOC</td>
<td>volatile organic compound</td>
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<td>VT</td>
<td>Virginia Tech</td>
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<td>WEMo</td>
<td>Wave Exposure Model</td>
</tr>
<tr>
<td>WSM</td>
<td>Watershed Simulation Model</td>
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<tr>
<td>WWTP</td>
<td>wastewater treatment plant</td>
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<tr>
<td>YSI</td>
<td>Yellow Springs Instruments, Inc.</td>
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Executive Summary

In Table ES-1, the titles of the following two research projects have changed.

<table>
<thead>
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<th>Research Project</th>
<th>Research Project Title and Outcome</th>
<th>Senior Researcher and Duration</th>
</tr>
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Outcomes and Benefits to the Base: Data derived from these research activities will be used to parameterize a model of sediment accretion and forecast the marsh response to stressors (amphibious maneuvers and sea-level rise). These data will also quantify the marsh response to fertilization by nitrogen (N) and phosphorus (P) (a potential mitigation strategy).


1.0 Introduction

No changes to this section.

2.0 Program Organization

The Defense Coastal/Estuarine Research Program (DCERP) is a collaborative effort between the Strategic Environmental Research Program (SERDP), the Naval Facilities Engineering Service Center (NAVFAC ESC), Marine Corps Base Camp Lejeune (MCBCL), and the RTI International (RTI) DCERP Team, which was selected to execute the objectives of SERDP’s Ecosystem Management Project. Figure 2-1 illustrates the overall organization and lines of communication of DCERP. This figure has been revised to update changes in personnel and changes to acronyms (e.g., NAVFAC ESC).
3.0 **DCERP Overarching Strategy**

No changes to this section.

4.0 **Purpose of the Research Plan**

4.1 **Objectives of the Research Plan**

No changes to this sub-section.

4.2 **Selection of Research Projects**

Table 4-1 lists the title of each research project and the project’s lead investigator; these projects will be discussed in detail in Section 5 of this report (*Module Research Projects*). The titles have changed for the following research project: CW-1 and T-1.

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<th>Research Project Title</th>
<th>Senior Researcher(s)</th>
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<td>AE-1</td>
<td>Develop and Deploy Microalgal Indicators as Measures of Water Quality, Harmful Algal Bloom (HAB) Dynamics, and Ecosystem Condition</td>
<td>Hans Paerl</td>
</tr>
<tr>
<td>Research Project</td>
<td>Research Project Title</td>
<td>Senior Researcher(s)</td>
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<tr>
<td>------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>AE-2</td>
<td>Quantifying and Predicting Watershed Inputs of Nutrients, Sediments, and Pathogens</td>
<td>Mike Piehler</td>
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<tr>
<td>AE-3</td>
<td>Developing Indicators of Ecosystem Function for Shallow Estuaries: Benthic Functional Responses in the NRE</td>
<td>Iris Anderson</td>
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<td>CW-1</td>
<td>Determine Responses of Marsh Vegetation and Accretion to Relative Surface Elevation</td>
<td>Jim Morris</td>
</tr>
<tr>
<td>CW-2</td>
<td>Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates</td>
<td>Mark Fonseca</td>
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<tr>
<td>CW-3</td>
<td>Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands</td>
<td>Craig Tobias</td>
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<td>CB-1</td>
<td>Short-Term Barrier Evolution Related to Storms and Land Use</td>
<td>Jesse McNinch</td>
</tr>
<tr>
<td>CB-2</td>
<td>Long-Term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics</td>
<td>Antonio Rodriguez</td>
</tr>
<tr>
<td>CB-3</td>
<td>Understanding the Top-down and Bottom-up Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices on MCBCL</td>
<td>Sarah Karpanty and Jim Fraser</td>
</tr>
<tr>
<td>T-1</td>
<td>Effects of Different Understory Restoration Management Options on Terrestrial Ecosystem Structure and Function</td>
<td>Norman Christensen</td>
</tr>
<tr>
<td>T-2</td>
<td>Effects of Habitat Management for Red-Cockaded Woodpeckers (RCWs) on Bird Communities</td>
<td>Jeffrey Walters</td>
</tr>
<tr>
<td>Air-1</td>
<td>Optimization of Prescribed Burning (PB) by Minimizing Smoke Emissions and Maximizing Vitality of Fire-Adapted Ecosystems</td>
<td>Karsten Baumann</td>
</tr>
<tr>
<td>Air-2</td>
<td>Nitrogen Deposition to Terrestrial and Aquatic Ecosystems</td>
<td>Wayne Robarge</td>
</tr>
</tbody>
</table>

4.3 Integrating DCERP Research and Monitoring

No changes to this sub-section.

4.4 Other Research and Monitoring Efforts Related to DCERP

No changes to this sub-section.

5.0 Module Research Projects

The following sections contain the description of the research projects for each of the five ecological modules (i.e., Aquatic/Estuarine, Coastal Wetlands, Coastal Barrier, Terrestrial, and Atmospheric). Specific information is provided for each research project, such as the research team, hypothesis to be tested, technical goals, technical approach, schedule and scheduling constraints, and budgetary information for each of the four implementation years.

5.1 Aquatic/Estuarine Module

5.1.1 Introduction

In the context of the MCBCL region, the Aquatic/Estuarine Module will examine the tidal reach of the NRE from the freshwater head of the NRE near Jacksonville, NC, to the tidal inlet at Onslow Bay. The following research projects (Table 5-1) address challenges that are associated with stresses imposed as a consequence of MCBCL or other direct anthropogenic activities. There have been no changes to Table 5-1.
Table 5-1. Aquatic/Estuarine Module Research Project Title, Senior Researcher, Benefit to MCBCL, and Duration of Project

<table>
<thead>
<tr>
<th>Research Project</th>
<th>Research Project Title and Outcome</th>
<th>Senior Researcher</th>
<th>Benefit to MCBCL</th>
<th>Duration of Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE-1</td>
<td>Develop and Deploy Microalgal Indicators as Measures of Water Quality, Harmful Algal Bloom Dynamics, and Ecosystem Condition</td>
<td>Hans Paerl</td>
<td>Outcomes and Benefits to the Base: This research project will establish baseline indicators against which to gauge the short- and long-term effects of management strategies aimed at protecting water quality and preserving the ecological integrity of the New River Estuary (NRE) and adjacent wetlands and coastal waters. This project will also produce a decision-support, Bayesian modeling tool for guiding adaptive monitoring and management and provide data needed to link watershed nutrient inputs to estuarine circulation and water quality simulation models.</td>
<td>7/2007–06/2011</td>
</tr>
<tr>
<td>AE-2</td>
<td>Quantifying and Predicting Watershed Inputs of Nutrients, Sediments, and Pathogens</td>
<td>Mike Piehler</td>
<td>Outcomes and Benefits to the Base: This research project will provide the Base with information on the sources of identified pollutants to help avoid actions under the Clean Water Act (CWA) related to impairment from fecal indicator bacteria (FIB), sediments, or chlorophyll a exceedances by identifying emerging problems and using data to inform remedial strategies. This project will also produce a decision-support modeling tool (i.e., Watershed Simulation Model [WSM]) for predicting watershed exports as a function of environmental forcing and land-use changes.</td>
<td>7/2007–6/2011</td>
</tr>
<tr>
<td>AE-3</td>
<td>Developing Indicators of Ecosystem Function for Shallow Estuaries: Benthic Functional Responses in the New River Estuary</td>
<td>Iris Anderson</td>
<td>Outcomes and Benefits to the Base: This research project will provide a cause-and-effect analysis or potential management actions that may be necessary to mitigate long- and short-term impacts of the Base on benthic processes responsible for modulating nutrient enrichment and supporting higher trophic levels in the NRE. This project will also produce a decision-support modeling tool (i.e., Estuarine Simulation Model [ESM]) for predicting estuarine responses to natural and anthropogenic disturbances.</td>
<td>7/2007–6/2011</td>
</tr>
</tbody>
</table>

5.1.2 Knowledge Gaps in Conceptual Model and Research Needs

No changes to this sub-section.

5.1.3 Benefit to MCBCL

No changes to this sub-section.

5.1.4 Proposed Research Projects—Aquatic/Estuarine

5.1.4.1 Research Project AE-1: Develop and Deploy Microalgal Indicators as Measures of Water Quality, Harmful Algal Bloom Dynamics, and Ecosystem Condition

There have been no changes to this research project.
5.1.4.2 Research Project AE-2: Quantifying and Predicting Watershed Inputs of Nutrients, Sediments, and Pathogens

**Senior Researcher:** Mike Piehler (University of North Carolina at Chapel Hill [UNC-CH])

**Supporting Researchers:** Rachel Noble (UNC-CH), Craig Tobias (University of North Carolina at Wilmington [UNC-W]) and Mark Brush (Virginia Institute of Marine Science [VIMS])

**Hypotheses:** No changes to this section.

**Technical Goals:** No changes to this section.

**Technical Approach**

**Methods:** An array of tidal creeks and tributaries spanning both regional spatial gradients and disturbance gradients will be instrumented (Figure 5-5). The location of these stations has changed since the original DCERP Research Plan. The stations used for this research project are the same stations that are used for the tributary creek monitoring activity of the Aquatic/Estuarine Module. Eight of these stations have been divided into two groups: Group A and Group B. This grouping is necessary because we only have enough equipment to sample four stations at a time. The station names and grouping include the following:

**Group A**
- Oligohaline—Airport Creek (Site 3), Southwest Creek (Site 4)
- Mesohaline—French Creek (Site 8), Codgel Creek (Site 7)

**Group B**
- Polyhaline—Traps Creek (Site 6), Courthouse Bay (Site 5)
- Backbarrier—Freeman Creek (Site 9), Gillets Creek (Site 10)

![Figure 5-5. Tributary creek sampling stations.](image-url)
5.1.4.3 Research Project AE-3: Developing Indicators of Ecosystem Function for Shallow Estuaries: Benthic Functional Responses in the New River Estuary

**Senior Researcher:** Iris Anderson (VIMS)

**Supporting Researchers:** Mark Brush (VIMS), Mike Piehler (UNC-CH), Carolyn Currin (National Oceanic and Atmospheric Administration [NOAA])

**Hypotheses:** No changes to this section.

**Technical Goals:** No changes to this section.

**Technical Approach:**

(c) **Methods:** The locations of two sites were changed since the original DCERP Research Plan. The first, Muddy Creek, was located in an artillery fan and was also not a good paired site with Traps Bay. This site was moved to the head of Courthouse Bay (Site 25) near two splash points and extensive shoreline development, making for an ideal impacted site to pair with the relatively pristine Traps Bay and including an active splash point in our design. The original Traps Bay (Site 26) site was moved to another section of the bay because it was too close to a detonation area. The other sampling sites are located at Jacksonville (Site 21), Southwest Creek (Site 22), Wallace Creek (Site 23), French Creek (Site 24), Freeman Creek (Site 27), and Gillets Creek (Site 28) (Figure 5-7).

![Figure 5-7. New River Estuary—benthic research stations.](image-url)
Measurements will be collected using a DataFlow system to perform surface mapping of water quality parameters (e.g., dissolved oxygen [DO], chlorophyll a, turbidity, colored dissolved organic matter [CDOM], salinity, and temperature). This will allow us to obtain high-resolution data in the shallow waters and tributary creeks to complement the DataFlow monitoring in the main channel (from Aquatic/Estuarine monitoring activity). In addition, if conditions allow, continuous measurements of photosynthetically active radiation (PAR), light attenuation, turbidity, CDOM, and chlorophyll a will be performed during MCBCL training maneuvers at specific splash zones within the NRE. During these intensive studies, continuous data will be collected by deploying logging data sondes and light sensors.

The proposed experimental methods have been modified for Years 2 and 3 to improve the design and to obtain even more data than originally planned. Initially, experiments were going to be conducted at four stations in Year 2 and at four stations in Year 3. Now experiments will be conducted at six stations in Year 2 (excluding the Intracoastal Waterway [ICW] sites). This will open up Year 3 to conduct a factorial experiment in which we manipulate light quality and quantity and nutrient loading, which will allow us to more conclusively test our hypotheses.

During Year 2, study sites in the low- to mid-mesohaline zone will be chosen in conjunction with the Coastal Wetlands Module. Sites will be stratified to assess the impacts of local and regional land use, including the role that wetlands play in mitigating the impacts of land use and improving light quality and quantity. During Year 3, study sites will be chosen in the high mesohaline and polyhaline zones, including backbarrier sites. Development of the ESM will take place during all years of the study. During Year 4, analyses of samples taken during the previous years will be completed, and these data will be used to validate the ESM developed during Years 1–3 and to test various scenarios using the ESM. Stations will be chosen within individual salinity regimes that reflect the range of disturbance within that regime. Studies will be performed during each of the four seasons.

Seasonally, we will measure the inherent optical properties of the water column at each site using a WET Labs, Inc. ac-spectra instrument (Gallegos et al., 2005) and will measure the three optically active constituents (i.e., turbidity, chlorophyll a and CDOM) in the water column by deploying both a WET Labs CDOM detector and a Yellow Springs Instruments, Inc. (YSI) data sonde that is fitted with wiped sensors for detecting PAR, light attenuation, DO, chlorophyll a fluorescence, turbidity, salinity, and temperature. We will supplement these measurements with laboratory analyses of particulate absorption, chlorophyll a, and total suspended solids (TSS). Radiative transfer modeling (Mobley, 1994) can then be used to predict apparent optical properties, specifically the diffuse attenuation coefficient Kd (Gallegos, 2001), which determines the amount and quality of light reaching the bottom, which in turn controls the rate of benthic microalgal production (Pinckney and Zingmark, 1993; Maclntyre and Cullen, 1996). We will measure the metabolism of benthic microalgae (BMA), the water column, and any dominant macroalgae by developing series of photosynthesis-irradiance curves in a light-gradient box (Goebel et al., 2006). Metabolic rates will be quantified from changes in DO concentrations over time as measured with a Hach optical DO sensor.

Concurrently, to determine the effects of ambient light conditions and nutrient enrichment on benthic–microalgal modulated fluxes of nutrients and on transformations of nutrients within sediments, sets of cores will be randomly taken at each sampling site, incubated in situ for 48 hours, and sampled at 6-hour intervals to determine metabolic and nutrient cycling rates, mineralization, and denitrification, as described by Anderson and colleagues (2003). Nitrogen mineralization will be measured using a 15NH4+ isotope-dilution technique (Anderson et al., 2003). Denitrification and N fixation will be measured following the addition of 15NO3− and using a combination of isotope-pairing and membrane inlet mass spectrometry techniques (An and Joyce, 2001). All isotopic analyses will be performed at UNC-W Center for Marine Science (CMS) via continuous flow on a Thermo Scientific Delta V isotope ratio mass spectrometer. To synthesize results from benthic and water column metabolic measurements and provide a useful indicator of disturbance, high-frequency time-series oxygen data from deployed sensors and the autonomous vertical profilers (Research Project AE-1) will be used to quantify total ecosystem metabolism.

During Year 3, manipulation experiments will be performed to better understand the roles that nutrient enrichment and light quality and quantity play in regulating ecosystem metabolism and nutrient cycling. Unlike the in situ experiments performed during Year 2, these experiments will involve a full factorial design with multiple nutrient concentrations and light levels under controlled conditions within an environmental chamber.

The results from Research Project AE-3 will be integrated with the results from Research Projects AE-1 and AE-2, and all other DCERP modules, and they will be scaled to the entire NRE using a mechanistic, spatially explicit ESM to predict biogeochemical cycling of carbon (C), N, P, and DO and food web dynamics from nutrient and sediment inputs through secondary production available to fish and shellfish. The modeling methods remain the same as in the original DCERP Research Plan. First, a two-layered box model of the system will be created to predict hydrodynamic exchanges among relatively coarse boxes arranged along the estuarine salinity gradient. This box model will allow us to focus on developing the biogeochemical and ecosystem formulations, which will be coupled to the highly resolved Advanced Circulation (ADCIRC) Model in Year 4 to develop the ESM.
5.2 Coastal Wetlands Module

5.2.1 Introduction
The following three research projects (Table 5-2) of the Coastal Wetlands Module address challenges that are associated with stresses imposed as a consequence of MCBCL and other direct anthropogenic activities and of global climate change, particularly sea-level rise. The title of Research Project CW-1 is the only change in Table 5-2.

Table 5-2. Coastal Wetlands Module Research Project Title, Senior Researcher, Benefit to MCBCL, and Duration of Project

<table>
<thead>
<tr>
<th>Research Project</th>
<th>Research Project Title and Outcome</th>
<th>Senior Researcher and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW-1</td>
<td>Determine Responses of Marsh Vegetation and Accretion to Relative Surface Elevation</td>
<td>Jim Morris</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> Data derived from these research activities will be used to parameterize a model of sediment accretion, forecast the marsh response to stressors (e.g., amphibious maneuvers, sea-level rise), and will quantify the marsh response to fertilization by N and P (a potential mitigation strategy).</td>
<td>7/2007–6/2011</td>
</tr>
<tr>
<td>CW-2</td>
<td>Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates</td>
<td>Mark Fonseca</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> This work will inform about shoreline stabilization and wetland restoration efforts and will assess the impacts of tactical vehicles.</td>
<td>7/2007–6/2011</td>
</tr>
<tr>
<td>CW-3</td>
<td>Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands</td>
<td>Craig Tobias</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> Data derived from these research activities will provide information on the value of the marshes as nutrient transformers and the magnitude of sub-surface nutrient flux to the estuary.</td>
<td>7/2008–6/2011</td>
</tr>
</tbody>
</table>

5.2.2 Knowledge Gaps in Conceptual Model and Research Needs
No changes to this sub-section.

5.2.3 Benefit to MCBCL
No changes to this sub-section.

5.2.4 Proposed Research Projects—Coastal Wetlands
Research projects proposed by the Coastal Wetlands Module address three major themes. Two of these research projects, CW-1 and CW-2, address changes in geomorphology driven by sea-level change, impacts from amphibious maneuvers, and wave erosion. Research Project CW-3 addresses the flux of shallow groundwater from upland areas through the marshes and the transformation of nutrients in ground water that transits the marsh. Research sites are strategically chosen to take advantage of significant activity (e.g., amphibious operations, splash points), proximity to upland land uses (e.g., groundwater, nutrient flux), research and monitoring by other modules (e.g., barrier island migration), or other significant attributes (e.g., shoreline stabilization structures).
Marsh research areas (Sites 1 and 2 in Figure 5-10) on the seaward side of the ICW are behind the barrier island and will provide information on how these landforms interact. For example, does the dune complex provide a sediment subsidy to the wetlands? How fast are the dunes migrating? Sites at Mile Hammock Bay near Tactical Landing Zone (TLZ) Bluebird (Site 3 in Figure 5-10) are located near landing craft air cushion (LCAC) amphibious training zones. Operations at one LCAC training zone have been discontinued and will provide information on the recovery rates of marshes. Results on marsh accretion and erosion obtained at the active LCAC training site will be contrasted with measurements made in the relatively undisturbed Freeman Creek (Site 1) and Onslow Beach Backbarrier (Site 2).

Figure 5-10 shows the locations of all of the research stations, as well as the monitoring stations because many of these activities are co-located.

- Site 1 (Freeman Creek): Moderate military use (G-10 impact zone runoff), higher salinity, and proximity to coastal barrier island
- Site 2 (Onslow Beach Backbarrier): Not-impacted by military use, high salinity, and proximity to coastal barrier island
- Site 3: (Mile Hammock Bay): High military use (LCAC): Closest proximity to the New River Inlet
- Sites 4 and 9 (French Creek, inside and outside splash point): Moderate impact (runoff from G-10 impact area, splash points at mouth) and lower salinity
- Sites 5 and 6 (Courthouse Bay, outside and inside splash point): Moderate impact from cantonment area and splash point and higher salinity
• Sites 7 and 8 (Highway 172 bridge, inside and outside): Moderate impact from boat traffic and moderate salinity
• Site 10 (Hospital Point): Area with a stabilized shoreline, low salinity, and wave exposure setting
• Site 11 (ICW): Area with a stabilized shoreline, high salinity, and wave exposure setting
• Site 12 (Traps Creek): Forested training lands and moderate salinity
• Sites 13 and 14 (Mile Hammock Bay and Gottschaulk Marina): Tide gauges.

5.2.4.1 Research Project CW-1: Determine Responses of Marsh Vegetation and Surface Elevation to Nutrients

| Senior Researcher: Jim Morris (University of South Carolina [USC]) |
| Supporting Researcher: Carolyn Currin (NOAA) |

Hypotheses: No changes to this section.
Technical Goals: No changes to this section.

Technical Approach

(b) Experimental Design:
The overall experimental design for this research project has not changed; however, the following text reflects changes to the stations for this experiment.

Hypothesis 1) Intertidal salt marshes will equilibrate at an elevation within the tidal frame that is inversely proportional to the rate of sea-level rise. Stations for this experiment will be established at Sites 1, 2, and 3 (see Figure 5-10). The parameter values in the model will be derived by repeated measurements of marsh surface elevation in plots that vary in treatment (see Hypothesis 3), as well as through the use of experiments designed specifically to define various response variables. One of these is a type of planter known as a “marsh organ” that raises or lowers the marsh surface experimentally. The device is planted with recruits taken from the neighboring marsh, and after a season of growth, the harvest of roots and shoots gives the biomass response to relative elevation, which is a critical relationship in the MEM2.

Hypothesis 2) The equilibrium elevation of salt marshes in sites where amphibious training reduces standing biomass density will decrease relative to undisturbed controls. Replicate (2) surface elevation table (SET) plots will be established at TLZ Bluebird (Site 3 in Figure 5-10) and the results contrasted with results obtained in control areas (Sites 1 and 2 in Figure 5-10). The hypothesis will be rejected if the biomass of Site 3 is lower than Sites 1 and 2 and the elevation of Site 3 rises at a lower rate than at Sites 1 and 2. An SET experiment will also be established at an adjacent site where amphibious landings have been discontinued. At that site, we expect to find that the marsh is recovering (biomass and elevation increasing). SETs will be used opportunistically, as well to take advantage of episodic events such as storms or training exercises.

Hypothesis 3) The equilibrium elevation of salt marshes can be increased by raising biomass density either by fertilization or by modifying the training schedule. A fertilization experiment with N plus P nutrients added to 1.5- x 1.5-m² plots of salt marsh will be replicated (3) and instrumented with SETs. The experiment will be conducted over 5 years to allow time for equilibration and inter-annual variability in mean sea level. During this time, the marsh elevation in the fertilized plots and controls will be monitored with an SET every 2 months. The hypothesis will be rejected if the elevation of these experimental plots does not increase relative to controls.

Hypothesis 4) The skewness of the frequency distribution of relative marsh elevation is a diagnostic of its vulnerability to sea-level rise or disturbance (e.g., storms, amphibious maneuvers). Light detection and ranging (LIDAR) data that are taken from the marsh surface will be analyzed and frequency distributions will be plotted and a skewness statistic will be computed for spatially distributed subsets of data. These skewness distributions will be mapped and regressed against absolute normalized elevations. Hypothesis 4 can be rejected if no correlation is found between absolute elevation and skewness.

(c) Methods: SETs were established at Sites 1–3. At Freeman Creek (Site 1), six SETs were established to support fine-scale (±2-mm vertical resolution) measures of marsh elevation change in response to nutrient additions. For this research project, the marsh vegetation that surrounds three of the SETs will be fertilized with N and P, which should dramatically increase biomass density. Comparison of the sedimentation rates in the three fertilized and the three control SET plots will allow us to assess the influence of biomass density on sedimentation rate and will provide an important parameter value for the MEM2. Twelve 1.5- x 1.5-m plots were established along the Freeman Creek boardwalk to support a factorial design for determining the limiting nutrient for marsh primary production (Figure 5-14b). At the Mile Hammock Bay (Site 3) and Onslow Beach Backbarrier (Site 2), only two SETs were installed at each: one will serve as a control, and the other will receive the +N+P fertilizer treatment.
applied quarterly as $P_2O_5$ and $(NH_4)_2SO_4$ at a rate of 15 mol m$^{-2}$ yr$^{-1}$ of P and 30 mol m$^{-2}$ yr$^{-1}$ of N (Figure 5-14A). Additional 2- x 2-m plots have been established at each site to accommodate two more replicates of the control and $+N+P$ treatments. At all 2- x 2-m plots, we will measure above-ground marsh primary production (end of season standing biomass) and sediment accretion using marker horizons.

Fertilizer treatment will be added seasonally during the growing season for 4 years. Biomass will be measured nondestructively in the plots, and marsh surface elevations will be measured every 2 months. At the conclusion of the experiment, the vegetation will be harvested and the model will be calibrated. Separate plots fertilized with only N or P will be used to determine the identity of the primary and secondary limiting nutrients, and plants will be harvested at the end of the season (EOS) for measurement of EOS biomass, and these measurements will be contrasted with EOS biomass measurements taken from nearby control plots.

The response of the marsh vegetation to relative marsh surface elevation will be measured using in situ, experimental planters (marsh organs) that simulate conditions at different positions within the tidal frame. Two marsh organs have been deployed at Freeman Creek (Site 1). One marsh organ will serve as the control and one marsh organ will be treated with N and P to determine if there is an interaction between relative elevation and fertility. The marsh organs will be harvested at the EOS, and the resulting data will show both the responses of above- and below-ground biomass to elevation. Below-ground biomass may have an important effect on marsh accretion or elevation change, and it is a variable that is needed to parameterize the MEM2.

Net primary production (NPP) will be measured nondestructively in plots where SET measurements are made. One nondestructive method requires a census and measurements of stem heights (Morris and Haskin, 1990). We have found that salt marsh NPP is highly correlated with EOS biomass (Morris, in press), as measured by summing stem heights, and we will use this technique, which will allow for a much greater spatial coverage than the labor intensive method of making monthly measurements.

High spatial resolution (ca. 1 m) multispectral data taken from satellite or aircraft will be classified to the level of major plant communities using a trained artificial neural network (Morris et al., 2005). Period imagery will be examined to identify changes in area, geometry, and position. LIDAR data will be used to map marsh elevations and to derive diagnostic frequency distribution, provided that LIDAR data with resolution less than 1 m are available.
(d) Data Analysis: (1) Marsh Sediment Accretion: No changes to the data analysis of this component.
(2) Model Synthesis: There have been new theoretical developments on the MEM2. These new developments relate to the inclusion of organic matter production and a more realistic description of the biomass response curve in the model. We are using a more sophisticated software package (currently Mathematica) that has the capability of solving equations symbolically. This software has allowed us to derive a more complex and more realistic version of the MEM2. This new, improved model is the one that we are currently planning to implement for the Base.
(3) Marsh Elevations: Preliminary analysis of current LIDAR data for MCBCL suggests that the spatial resolution of the data is on the order of 20 m. We need data that has a posting density of approximately 1 m. We have not yet obtained multispectral imagery needed to classify the LIDAR data. If high-resolution LIDAR data are not available, we will use the elevation response curve from the marsh organs with global positioning system estimates of the present marsh elevations (from monitoring activities) to evaluate where the marshes lie relative to the tipping point.

Scheduling Constraints: No changes to this section.

Year 1 Go/No Go Decision Point: No changes to this section.

Budget (Estimated): No changes to this section.

5.2.4.2 Research Project CW-2: Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates

| Senior Researcher: Mark Fonseca (NOAA) |
| Supporting Researcher: Carolyn Currin (NOAA), Amit Malhotra (NOAA) |

Hypotheses: No changes to this section.

Technical Goals: No changes to this section.

Technical Approach: No changes to this section.

Scheduling Constraints: No changes to this section.

Year 1 Go/No Go Decision Point: If we cannot successfully calibrate the WEMo model for the NRE shoreline, development of the New River Estuary Shoreline Erosion (NRESE) model will be a No Go because we will not be able to obtain a spatially explicit estimate of wave energy to accompany measures of shoreline erosion, vegetation, and sediment accretion for use in the NRESE model.

We are on schedule to be able to successfully calibrate the WEMo and do not foresee any reason not to accomplish our research project goals.

Budget (Estimated): No changes to this section.

5.2.4.3 Research Project CW-3: Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands

| Senior Researcher: Craig Tobias (UNC-W) |
| Supporting Researcher: Jim Morris (USC) |

Hypotheses: No changes to this section.

Technical Goals: No changes to this section.

Technical Approach:
(b) Experimental Design: Linear arrays of piezometers will be established along transects through different three marsh sites parallel to the flow path. The sites originally proposed were Wallace, Freeman, and Gillets creeks. The site locations have been changed to French Creek, Traps Bay, and Freeman Creek. Freeman Creek (Site 1) was selected because it represents a tidally dominated euryhaline marsh, and it is co-located with other Coastal Wetlands Module monitoring activities and research projects. French Creek (Site 4) was selected because of its proximity to the G-10 impact area and its proximity to the MCBCL wastewater treatment plant. French Creek is also a representative meso-oligohaline, irregularly flooded marsh that is characteristic of the upper NRE. Traps Creek (Site 12) is a representative mesohaline, mixed-vegetation, pocket-marsh ecotype that is bisected by an incised stream channel. French and Traps creeks will serve nicely as model marshes because of their respective ecotypes in terms of geomorphology, biology, and hydrology.
5.3 Coastal Barrier Module

5.3.1 Introduction

The proposed research projects of the Coastal Barrier Module build upon the monitoring data, are linked within the module and between modules, and address the most pressing military drivers and goals (Table 5-3). The research projects will use the monitoring data to develop maps of shoreline change and the underlying cause for spatial variations in coastal retreat rates, as well as make recommendations to enhance the Base’s shorebird monitoring protocol. Conceptual models that predict the morphology and location of the shoreline will be developed. Barrier response to extreme storm events and the rate of recovery will be derived. There have been no changes to Table 5-3.

<table>
<thead>
<tr>
<th>Research Project</th>
<th>Research Project Title and Outcome</th>
<th>Senior Researcher and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> This project will help mitigate Onslow Beach erosion that results from natural impacts (e.g., storms, climate, and sea level), training activities, and management practices.</td>
<td></td>
</tr>
<tr>
<td>CB-2</td>
<td>Long-Term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics</td>
<td>Tony Rodriguez 7/2009-6/2011</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> This project will assess the principle drivers of Onslow Beach erosion, including natural (e.g., storms, climate, sea-level rise, underlying geology) and anthropogenic (e.g., training activities and management practices) stressors.</td>
<td></td>
</tr>
<tr>
<td>CB-3</td>
<td>Understanding the Top-Down and Bottom-Up Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices on MCBCL</td>
<td>Sarah Karpanty and Jim Fraser 7/2007–7/2010</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> Results will be used to develop efficient monitoring protocols and conservation management procedures for shorebirds and seabirds and to best design mitigation in the case of beach nourishment or the introduction of new uses to the coastal barrier ecosystem. Pilot studies of predator top-down influences will allow MCBCL to design the most efficient use of trapping resources and minimize the frequency of trapping and the co-occurrence of trapping efforts with human uses of the coastal barrier islands.</td>
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</tbody>
</table>

5.3.2 Knowledge Gaps in Conceptual Model and Research Needs

No changes to this sub-section.

5.3.3 Benefit to MCBCL

No changes to this sub-section.

5.3.4 Proposed Research Projects—Coastal Barrier

5.3.4.1 Research Project CB-1: Short-Term Barrier Evolution Related to Storms and Land Use

There have been no changes to this research project.
5.3.4.2 Research Project CB-2: Long-Term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics

There have been no changes to this research project.

5.3.4.3 Research Project CB-3: Understanding the Top-Down and Bottom-Up Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices on MCBCL

**Senior Researchers:** Sarah Karpanty (Virginia Tech [VT]) and Jim Fraser (VT)

**Supporting Researcher:** Pete Peterson (UNC-CH)

**Hypotheses:** No changes to this section.

**Technical Objectives/Goals:** No changes to this section.

**Technical Approach:**

(c) Methods: There have been no changes to the methods of Research Project CB-3; however, the location of the stations was not indicated in the original DCERP Research Plan. Figure 5-21 shows the location of the cameras for predator evaluation (Sites 22–37), as well as the other stations for the Coastal Barrier Module monitoring and research program. Sixteen camera sites are equally divided between the ocean side and marsh side of the coastal barrier island with eight sites in the northeast recreational use portion of the island and eight in the southwest military-use portion of the island (Table 5-4b).

![Figure 5-21. Coastal Barrier Module monitoring sites.](image)
Table 5-4b. Monitoring and Research Stations for the Coastal Barrier Module

<table>
<thead>
<tr>
<th>Hydrodynamics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1: Riseley Pier</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Barrier Morphology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 3: South Onslow Beach, training</td>
<td>Site 10: South Onslow Beach, training</td>
</tr>
<tr>
<td>Site 4: South Onslow Beach, training</td>
<td>Site 11: North Onslow Beach, recreation (Focus Site 19)</td>
</tr>
<tr>
<td>Site 5: South Onslow Beach, training (Focus Site 16)</td>
<td>Site 12: North Onslow Beach, recreation</td>
</tr>
<tr>
<td>Site 6: South Onslow Beach, training (Focus Site 17)</td>
<td>Site 13: North Onslow Beach, recreation (Focus Site 20)</td>
</tr>
<tr>
<td>Site 7: South Onslow Beach, training</td>
<td>Site 14: North Onslow Beach, recreation</td>
</tr>
<tr>
<td>Site 8: South Onslow Beach, training (Focus Site 18)</td>
<td>Site 15: North Onslow Beach, recreation (Focus Site 21)</td>
</tr>
<tr>
<td>Site 9: South Onslow Beach, training</td>
<td></td>
</tr>
</tbody>
</table>

| Focus Sites (Sedimentology and Benthic Invertebrate Monitoring) |               |
| Site 16: ORRVs with overwash behind the beach | Site 19: Amphibious landings (low-use training activity) |
| Site 17: ORRVs with salt marsh behind the beach | Site 20: Extensive human disturbance |
| Site 18: Amphibious landings (high-use training activity) | Site 21: Limited human disturbance |

| Camera-Trapping Locations                        |               |
| Site 22: Oceanside, south training, facing southeast | Site 30: Marsh, north recreation |
| Site 23: Oceanside, south training, facing northeast | Site 31: Marsh, north recreation |
| Site 24: Oceanside, south training, facing southeast | Site 32: Marsh, north recreation |
| Site 25: Oceanside, south training, facing southeast | Site 33: Marsh, north recreation |
| Site 26: Oceanside, north recreation, facing southeast | Site 34: Marsh, south training |
| Site 27: Oceanside, north recreation, facing southeast | Site 35: Marsh, south training |
| Site 28: Oceanside, north recreation, facing southeast | Site 36: Marsh, south training |
| Site 29: Oceanside, north recreation, facing southeast | Site 37: Marsh, south training, facing northeast |

**Scheduling Constraints:** No changes to this section.

**Year 1 Go/No Go Decision Point:** No changes to this section.

**Budget (Estimated):** No changes to this section.
5.4 Terrestrial Module

5.4.1 Introduction

The two research projects proposed for the Terrestrial Module (Table 5-5) constitute an integrated program that is designed to provide a greater understanding of how forest management, and especially PB, affect plant and animal communities across the soil-moisture gradient. The relationship between RCW foraging habitat quality and community composition will be an outcome of this understanding. These research projects build upon the vegetation monitoring proposed for the Terrestrial Module, which will provide much of the data to be used in assessing relationships between management and community composition.

<table>
<thead>
<tr>
<th>Research Project</th>
<th>Research Project Title and Outcome</th>
<th>Senior Researcher and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>Varying Prescribed Fire Regimes and Forest Management Effects on Terrestrial Ecosystem Structure and Function</td>
<td>Norman Christensen</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> The results of this research project will provide measures of the effects of military and forestry activities on plant and animal communities and guidance on how best to mitigate any adverse effects of such activities.</td>
<td>1/2008–6/2011</td>
</tr>
<tr>
<td>T-2</td>
<td>Effects of Habitat Management for Red-Cockaded Woodpeckers on Bird Communities</td>
<td>Jeffrey Walters</td>
</tr>
<tr>
<td></td>
<td><strong>Outcomes and Benefits to the Base:</strong> The outcomes of this research project will be an efficient method to measure quality of RCW habitat over a large spatial extent and analysis of effects of management on not only the endangered RCW, but also another species at risk, the Bachman’s sparrow.</td>
<td>1/2008–6/2011</td>
</tr>
</tbody>
</table>

5.4.2 Knowledge Gaps in Conceptual Model and Research Needs

No changes to this sub-section.

5.4.3 Benefit to MCBCL

No changes to this sub-section.

5.4.4 Proposed Research Projects—Terrestrial

5.4.4.1 Research Project T-1: Effects of Different Understory Restoration Management Options on Terrestrial Ecosystem Structure and Function

This research project was revised and submitted to SERDP in June 2008.

**Senior Researcher:** Norm Christensen (Duke)

**Supporting Researcher:** Jeff Walters (Virginia Tech)

**Hypotheses:**

1. Herbaceous cover, productivity, and species diversity will increase with increasingly aggressive measures to remove understory hardwood shrubs and trees and control the reproduction of these trees and shrubs (mechanical thinning, herbicide, and mechanical thinning plus herbicide).
2. These effects will vary depending on the season of mechanical thinning (growing season versus dormant season).
3. Effects of restoration treatments will be further augmented by mechanical removal of forest floor and thick organic duff.
4. Artificial seeding of native herbaceous species will significantly accelerate the restoration of understory herbaceous communities and will facilitate the restoration of low-intensity, high-frequency fire regime.
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5. Changes in the composition, productivity, and diversity of the herbaceous community will be highly correlated with variations in the composition of insect and bird communities.
6. Forest management activities will have their greatest impacts on species richness and composition in moister sites compared to dryer sites.

Technical Objectives/Goals: Measure impacts of different forest understory and midstory control techniques (mechanical operations with HydroAx, herbicide, mechanical plus herbicide) and different seasons (growing versus dormant) of mechanical operations on forest stand and herbaceous layer cover, composition, production, and diversity, and the abundance of key insect and bird species. Research Project T-1 will provide an understanding of the mechanistic connections among trophic levels that determine avian habitat (particularly RCW). This research will focus on numerous data gaps including the following:
1. Effects of variations in understory forest restoration techniques
2. Impacts of forest restoration management on herbaceous communities and the interaction of those activities with fire management
3. Connections between restoration of herbaceous communities and habitat for insect and bird communities
4. Improved understanding of the variations in these effects among different site conditions within the general loblolly pine plantation forest type.

These results will bear directly on Base forest management objectives, including the following:
1. Restoration of longleaf pine habitat
2. Recovery of RCW populations
3. Conservation of native biological diversity
4. Support for military maneuvers—Expansion of available training area by opening understory, facilitating troop movement
5. Promoting sustainable forest management
6. Improving knowledge of fire and fuel management

Conditions for the Project: Thirty- to 60-year-old stands dominated by loblolly pine with a robust understory and hardwood midstory are widespread at MCBCL and are a central target for restoration management by the MCBCL staff.

Technical Approach
(a) Background: The research projects in the Terrestrial Module primarily focus on critical knowledge gaps related to efforts to restore longleaf pine ecosystems on sites across MCBCL that have been modified by past forest management activities. Specifically, the Terrestrial Module team will examine the effects of alternative understory restoration strategies (e.g., mechanical operation, herbicide application, prescribed fire) on understory plant and insect communities and, ultimately, on avian habitat (particularly habitat for RCWs). Land use and forestry activities over the past two centuries have converted tens of thousands of acres of the MCBCL terrestrial landscape from longleaf pine-dominated forests to forests dominated by loblolly pine and hardwoods. This transformation has been extensive on many of the most productive sites that occur along the soil moisture gradient between well-drained sandy soils and organic soils in pocosins.

Over the past 50 years, many areas were purposefully planted in loblolly pine following harvest activities. Most of these sites were protected from fire, resulting in substantial in-growth of intermediate height hardwoods, such as wax myrtle, and the accumulation of a thick organic forest floor and duff. These forests support considerably less herb-layer diversity and productivity than their pre-disturbance counterparts. Little is known about their insect fauna, but current conditions in these forests do not provide a suitable habitat for those avian species that are typically found in longleaf pine ecosystems. Furthermore, hardwood in-growth and forest floor accumulation are significant challenges to the restoration of the high frequency, low-intensity fire regimes necessary to restore longleaf pine ecosystems (ESA 2007; Nowacki and Abrams, 2008).

In some parts of MCBCL, restoration has taken the form of clear cutting, followed by planting of longleaf pine and eventual reestablishment of an appropriate prescribed fire program. Restoration of mature longleaf habitat by this approach will require many decades. As an alternative strategy to accelerate habitat restoration, MCBCL staff has implemented thinning treatments to reduce overstory tree density (40–60 ft²/acre), remove mid-story hardwoods, and create open-stand structure and understory composition and fuels that are more typical of longleaf pine ecosystems. Such management is currently being applied to hundreds of MCBCL acres each year. Variations on this management theme include different seasons (growing/dormant) of mechanical control of the woody understory and the use (or not) of herbicides. All such areas receive a late winter/early spring prescribed fire in the year following treatment.

Currently, restoration treatments do not include specific actions related to reducing forest floor duff or exposing mineral soil, even though these features are known to influence both fire behavior and patterns of understory plant establishment and growth. Prescribed fire is used to reduce duff and coarse woody over time, but may result in more intense soil heating. In moist situations, this duff layer resists burning. In addition, patterns of vegetation change following such treatments are likely influenced by the availability of seed of longleaf ecosystem species.

Dr. Joan Walker of the USDA Forest Service is currently performing other SERDP-sponsored research to examine patterns of establishment of longleaf pine in response to overstory and midstory thinning treatments. Their specific effects on other understory components (e.g., vegetation, forest floor, and fuels), insects, and avifauna have not been studied.

The needs of RCWs are well known, but virtually nothing is known about the community dynamics between the plants at the base of the food chain and the RCW at the top or within the consumer community at the top, beyond the RCW (U.S.
The two research projects (T-1 and T-2) planned for the Terrestrial Module constitute an integrated program designed to provide a greater understanding of how forest restoration treatments (e.g., mechanical and herbicide removal of woody understory, manipulation of the forest floor, and additions of seeds of herbaceous species) affect plant and animal communities across the soil-moisture gradient relevant to such management. The relationship between the RCW foraging habitat quality and herb and insect community composition will be an outcome of these projects. These research projects will build on the vegetation monitoring proposed for the Terrestrial Module, which will provide much of the data to be used in assessing relationships between management and plant community composition. The two Terrestrial Module research projects include more components that add to that foundation, specifically experimental plots and sampling of more plant, insect and avian components of the community.

**Dependent variables will include:**
- Herbaceous layer species composition and relative abundance (annually sampled). In addition, fuel amounts will be measured after Andrews and Bradshaw (1997).
- Herbaceous biomass and fuels (continuous)
- Insect species composition and abundance (sampled throughout each year)

This research will be carried out in 30-60 year old loblolly pine stands that are slated for eventual restoration to longleaf pine. A series of experimental treatment areas spanning the range of species composition and management activities will be monitored for vegetation change, structure, and species richness. There will be six treatments: 1) no woody understory/midstory removal, 2) mechanical understory/midstory removal—dormant season, 3) mechanical understory/midstory removal—growing season, 4) herbicide application, 5) mechanical plus herbicide application—dormant season, and 6) mechanical plus herbicide application—growing season. Understory restoration treatments will be performed in conjunction with MCBCL’s on-going forestry restoration management program. Restoration treatment units will be sufficiently large (>20 acres) to accommodate simultaneous bird community studies to be undertaken by Research Project T-2. All treatments will receive non-growing season prescribed burns (PBs) at 3-year intervals. Each of the six treatments will be replicated at three different locations (i.e., 18 treatment areas). Differences among treatments might also be included. Past fire and land use history will be determined and herb/shrub layer compositional variations will be sampled in identified stands for which such information is currently unavailable. Such stands typically comprise many tens of acres and extend across a gradient of soil-moisture conditions.

**Independent variables will include:**
- Soil/site moisture. A range of soil/site moisture conditions exists in each stand. These conditions will be measured and treated as a continuous variable and characterized by soil organic matter and depth to water table.
- Addition of native herbaceous seed. To be done on small (10 x 10 m) plots within the experimental plots
- Manipulation of forest floor and surface organic duff. To be done on small (10 x 10 m) plots within experimental plots.

**Midstory and understory hardwood removal using growing season and dormant season HydroAx treatments, herbicide, and the combination of HydroAx and herbicide treatments.**

**Soil/site moisture. A range of soil/site moisture conditions exists in each stand. These conditions will be measured and treated as a continuous variable and characterized by soil organic matter and depth to water table.**

**Addition of native herbaceous seed. To be done on small (10 x 10 m) plots within the experimental plots**

**Manipulation of forest floor and surface organic duff. To be done on small (10 x 10 m) plots within experimental plots.**

**Methods:**

1. Working with MCBCL staff, stands slated for forest management restoration will be identified across MCBCL. This will mostly involve areas now dominated by loblolly pine, although some areas now supporting longleaf pine or pond pine might also be included. Past fire and land use history will be determined and herb/shrub layer compositional variations will be sampled in identified stands for which such information is currently unavailable. Such stands typically comprise many tens of acres and extend across a gradient of soil-moisture conditions.

2. Within each treatment area, three 1 ha experimental plots will be monitored before and after the treatment applications for species abundance, diversity, cover of herbs, and biomass of woody plants using the methodology established by the North Carolina Vegetation Survey protocol (Peet et al., 1998) as described in the DCERP Baseline Monitoring Plan (RTI, 2007b). In each experimental plot insect/arthropod populations will be monitored in soil-level pit-fall or sticky traps, by sweep-netting surface vegetation, and in traps positioned at standard heights on tree boles (Provencher et al., 2000a & b). Insects will be euthanized and identified in the laboratory to the lowest taxon possible. Bird composition and abundance will be assessed from point vocal samples located across each treatment area at several times throughout the breeding season.

3. Within the 1-ha experimental plots in each treatment, smaller scale (10- x 10-m treatment plots) experiments will be designed to examine the effects of soil surface organic layer removal and addition of seed of native herbaceous species on the development of understory communities. Herb sampling will be adapted from the CVS protocols (Peet et al., 1998). Such treatments will include raking of forest floor duff, soil tilling/disking, and planting seeds of native longleaf ecosystem herbs collected on MCBCL. These treatments cannot be established until the year following mechanical/herbicide treatments. These effects are likely to be significant and might be the focus of future experiments undertaken at much larger scales.

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**Data Analysis:** Data will be analyzed using standard parametric approaches such as analysis of variance and regression. Novel multivariate analyses will include non-metric multidimensional scaling (McCune and Grace, 2002), CART® analysis and Mantel’s comparisons (Mantel, 1967). Changes in fuel conditions will be measured and used to estimate fire risk in the context of USFS fire danger rating models (Andrews and Bradshaw, 1997).

**Environmental Tools, indicators and other Outcomes:**
Potential environmental tools and indicators to come from this project include the following:
- Refinement of forest restoration protocols for pine stands that accelerate restoration to herb, insect, and bird communities typical of longleaf pine ecosystems.
- Species indicators (including alien species) of environment and management regime. This will address Base needs to understand consequences of variation in forest restoration activities on plant and animal abundance and diversity and provide the basis for optimizing management activities with respect to location and timing.
- Indicators of habitat quality for RCW and other avian species. This will include a mechanistic understanding of the connection between fire, management, and the RCW by providing information on trophic connections.

**Linkages to other Modules:**
This research project will provide direct linkages to the following:
- Directly supports Research Project T-2 related to RCW recovery and management.
- Research Project Air-1 will likely take advantage of prescribed burn activities associated with this research to evaluate optimization of prescribed burnings evaluate optimization of prescribed burnings by minimizing smoke emissions and maximizing vitality of fire-adapted ecosystems.
- Results will improve the design and interpretation of terrestrial vegetation baseline monitoring program.

**Military Drivers:** This project directly addresses military drivers #4, ensuring that MCBCL supports all required military training activities while complying with the ESA, and other wildlife requirements.

**Benefit to MCBCL:** Results from this research will be directly applicable to MCBCL’s forest restoration program, as well as efforts to restore and manage at-risk (e.g., RCW) species. (Military Driver #4) Compliance with the ESA is an important part of protecting Camp Lejeune’s primary mission of training and maintaining combat ready troops. Successfully complying with the ESA enhances the future training uses of the Camp Lejeune ranges, training areas and airspace.

**Schedule:**
- Identify and locate experimental locations (3) (working with MCBCL staff) treatment areas (6) within each of these locations. Work with MCBCL staff to develop specific management prescriptions. (7/2008 –12/2009)
- Establish experimental plots. 1 ha plots will be located and sampled within each treatment area (4/2009).
- Experimental treatments will be implemented winter and late spring of 2009. Within plot treatments such as seeding and forest floor manipulations will be initiated in summers of 2009 and 2010.
- Prepare interim report (2/2011).

**Budget (Estimated):**
- Year 1 (July 2007 – June 2008): 0
- Year 3 (July 2009 – June 2010): $ 141,226
- Year 4 (July 2010 – June 2011): $ 123,380
- Total (July 2007 – June 2011): $ 401,540

**Research Project T-2: Effects of Habitat Management for Red-Cockaded Woodpeckers on Bird Communities**

**Senior Researcher:** Jeffrey R. Walters (VT)

**Hypotheses:** No changes to this section.

**Technical Objectives/Goals:** No changes to this section.

**Technical Approach:** No changes to this section.
5.5. Atmospheric Module

5.5.1 Introduction

Research Projects Air-1 and Air-2 represent research in the areas of prescribed burning and nitrogen deposition, respectively (Table 5-6). These areas will enable MCBCL to understand its ecosystem’s sensitivity to proper forest management, nutrient loadings to sensitive waters, and impacts from off-site sources, such as confined animal feeding operations. The location of Research Project Air-1 studies will be a function of vegetation monitoring sites and research sites selected for the Terrestrial Module.

Table 5-6. Atmospheric Module Research Project Title, Senior Researcher, Benefit to MCBCL, and Duration of Project

<table>
<thead>
<tr>
<th>Research Project</th>
<th>Research Project Title and Outcome</th>
<th>Senior Researcher and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-1</td>
<td>Optimization of Prescribed Burning (PB) by Minimizing Smoke Emissions and Maximizing Vitality of Fire-Adapted Ecosystems</td>
<td>Karsten Baumann</td>
</tr>
<tr>
<td></td>
<td>Outcomes and Benefits to the Base: This project will provide an innovative land management tool that can also be used for implementing the Smoke Management Plan (SMP) of the NRE region and other populated regions in the southeastern United States.</td>
<td>7/2008–6/2011</td>
</tr>
<tr>
<td>Air-2</td>
<td>Nitrogen Deposition to Terrestrial and Aquatic Ecosystems</td>
<td>Wayne Robarge</td>
</tr>
<tr>
<td></td>
<td>Outcomes and Benefits to the Base: The results from this research project will provide information on the amount and composition of atmospheric deposition (especially for N) to the terrestrial and aquatic ecosystems that will be used to model the atmospheric N contribution to the total N budget for the NRE. This project will also provide information on the amount and distribution of rainfall across MCBCL.</td>
<td>7/2007–6/2011</td>
</tr>
</tbody>
</table>

5.5.2 Knowledge Gaps in Conceptual Model and Research Needs

No changes to this section.

5.5.3 Benefit to MCBCL

No changes to this section.

5.5.4 Proposed Research Projects—Atmospheric

5.5.4.1 Research Project Air-1: Optimization of Prescribed Burning (PB) by Minimizing Smoke Emissions and Maximizing Vitality of Fire-Adapted Ecosystems

<table>
<thead>
<tr>
<th>Senior Researcher:</th>
<th>Karsten Baumann (Atmospheric Research &amp; Analysis, Inc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotheses:</td>
<td>No changes to this section.</td>
</tr>
<tr>
<td>Technical Objectives/Goals:</td>
<td>No changes to this section.</td>
</tr>
<tr>
<td>Technical Approach:</td>
<td>This research contributes data to help fill gaps, including the following:</td>
</tr>
</tbody>
</table>
1. Effects of variations in fire regimes (e.g., frequency, season, intensity of fire) along fuel and moisture gradients
2. Connections between fire regimes, herbaceous communities, and habitat for insect and bird communities
3. Improved understanding of these PB effects at the moist (e.g., pocosin, end of the moisture) gradient.

The goal of this research is to collaborate with Research Project T-1 and MCBCL land managers to identify the critical points in the fuel model that allow the implementation of a parameterization scheme. This requires that the research field measurements cover a minimum level of fuel variability to enable a statistically robust parameterization of PB emissions towards the development of an accurate emissions forecasting tool.

Since the development of Research Project Air-1, Research Project T-1 has been re-designed and the burn season is no longer an independent variable in T-1. Instead, all T-1 plots will experience only dormant season burns subject to the Base's normal 3-year PB rotation. PBs are conducted exclusively by the MCBCL foresters, so that the Air-1 PB emission measurements will need to be coordinated with MCBCL. Plots from the Terrestrial Module’s vegetation monitoring and Research Project T-1 will provide the estimates of the actual fuel consumption, which is critically important for determining PB species’ emission factors and links to fuel condition and other direct and indirect combustion parameters, such as carbon monoxide/carbon dioxide (CO/CO₂) (combustion intensity) and terrain and meteorology, respectively. Of greatest interest to the MCBCL land managers, and the most important objective of Research Project Air-1, is to capture PB emissions during both growing and dormant seasons and to compare their respective atmospheric effects. The experimental design and methods for Research Project T-1 will be evaluated and potentially re-designed before the anticipated start of this project in July 2009.

**Scheduling Constraints:** No changes to this section.

**Year 1 Go/No Go Decision Point:** None specified; however, Research Project Air-1 depends on the success of Research Project T-1, as well as the Terrestrial Module’s monitoring program to establish an appropriate number of vegetation plots. If an appropriate number of vegetation plots cannot be established, then Air-1 will be a NO GO. We anticipate reaching this decision point in June 2009.

**Budget (Estimated):** No changes to this section.

### 5.5.4.2 Research Project Air-2: Nitrogen Deposition to Terrestrial and Aquatic Ecosystems

**Senior Researchers:** Wayne P. Robarge (North Carolina State University)

**Hypothesis:** No changes to this section.

**Technical Objectives/Goals:** No changes to this section.

**Technical Approach:**

_Wet Deposition:_ This project originally planned to use National Atmospheric Deposition Program (NADP)-certified wet deposition collectors to obtain rainfall samples. However, a decision was made to switch to an approved Mercury Deposition Network (MDN) collector after receiving comments during the poster presentation at the 2007 NADP Technical Meeting and during extensive discussions with Dr. David Gay, who is the NADP Acting Program Coordinator and MDN Coordinator. Dr. Gay indicated that results from the MDN collector would be acceptable for characterizing wet deposition chemistry without making any special modifications, and if emphasis changed in the near future to mercury deposition, the needed equipment would already be in place and would conform to existing MDN collection protocols. He also emphasized that the current design of the existing NADP-certified collectors may be changed in the near future; therefore, any collectors purchased for this project may no longer be certified in 4 or 5 years as approved for rainfall collection and certification. The switch from the NADP-style rainfall collectors to the approved MDN collectors was possible without incurring any additional costs to the project. Samples will be collected at four locations each week and analyzed for pH, soluble cations (i.e., ammonium, magnesium, calcium, sodium potassium), soluble anions (i.e., chloride, nitrate, nitrite, sulfate), and total DON and DOC.

There has been no change in the approach for measuring the spatial variability of rainfall using tipping bucket gauges. The location of the gauges will be slightly different than shown in Figure 5-25 of the DCERP Research Plan; the revised locations were not available at time of this addendum.

There have been no changes to the methods for determining dry deposition.
6.0 Data Management Module

No changes to this section.

7.0 Military Activity Impact

To be able to make appropriate management decisions about the effects of military training activities on MCBCL’s natural resources, it is important to understand the military stressors that impact the environment, assess the site-specific impact of those stressors, and evaluate their contribution to site degradation in comparison to those impacts resulting from non-military, legacy, and natural perturbations.

This approach will include a five-step process. For Step 1, RTI staff will identify, acquire, and review existing literature on military impacts to the various ecosystem types present at MCBCL (e.g., estuarine, wetlands, coastal barrier, and terrestrial). Step 2 will involve meetings with the Terrestrial Module Team that will be developing a land cover/land use geographic information systems (GIS) data layer; MCBCL range control staff; and the DCERP On-site Coordinator (OSC) to discuss the nature and extent of the observed impacts of training activities, what training activities or vehicles result in observable ecosystem impacts, and the extent of movements of troops and various training vehicles across MCBCL. There have been no changes to these first two steps.

In Step 3, RTI’s contractor (URS Corporation), the designer of the Range Facility Management Support System (RFMSS), was originally proposed to develop and conduct queries to extract real-time data from RFMSS on use of the Base’s land and estuarine and coastal waters, including the vehicles/watercraft types used and the number of troops involved in individual training maneuvers in various ecosystems. In meeting with MCBCL and reviewing RFMSS data, it was determined that Dr. Pat Halpin of the Terrestrial Module could query this database; therefore, it would not be necessary to contract with the URS Corporation to complete this step. As a result of preliminary queries, it was determined that RFMSS is used as a planning tool and adequately provides information on usage at the necessary spatial and temporal scales. Therefore, the RFMSS cannot be combined with GIS data to determine spatial dispersion of military training impacts as initially planned for Step 4. Instead, a scientific framework is being developed by SERDP and the DCERP OSC for each DCERP Module Team to evaluate the potential impact of military training activities on each ecosystem at various temporal and spatial scales. At the time of this addendum, the framework had not yet been developed. This framework would be used to determine potential indicators of military impacts for each module to fulfill Step 5 of the process.

8.0 Quality Assurance

No changes to this section.

9.0 Transition Plan for Research Results

No changes to this section.
10.0 Measures of Success
No changes to this section.

11.0 Literature Cited
No changes to this section.
Appendix E

Ecosystem Module Roadmaps
HYDRODYNAMICS
Stream flow and discharge (New River and tidal creeks)

WATER CHEMISTRY
Nutrients, salinity, pH, dissolved oxygen, temperature (New River, NRE, and tidal creeks)

SEDIMENTOLOGY
Total suspended solids (New River and tidal creeks); turbidity (NRE)

BILOGY
Primary productivity, phytoplankton, fluorescence (NRE)

AQUATIC/ESTUARINE MODULE

RESEARCH PROJECTS

AE-1: Develop and Deploy Microalgal Indicators as Measures of Water Quality
- Nutrient addition bioassays
- Identify nutrient limitations
- Identify nutrient loadings and ratio thresholds

AE-2: Quantify and Predict Watershed Inputs of Nutrients, Sediments, and Pathogens
- Non-point source (NPS) sediment loadings
- NPS nutrient loadings
- Fecal Indicator Bacteria (FIB) loadings

AE-3: Developing Indicators of Ecosystem Function – Benthic Functional Responses
- Rates of productively/ripiration
- Net ecosystem metabolism
- Sediment/water DIN flux
- Denitrification efficiency
- Sediment/dissolved oxygen profile
- Benthic community composition/abundance

OUTCOMES

Establish indicator to gauge effects of management strategy on water quality
Adaptive nutrient management
Calibrate remote sensing model
GIS maps of microalgal community composition and verify eutrophication models to forecast blooms

Develop proactive approach to avoid CWA 303(d) impairments
Assess thresholds of minimum sediment loading to support marsh accretion
Develop FIB to distinguish fecal contamination from loading to the NRE
Provide site-specific data on baseflow vs. storm flow loadings of NPS pollution

BAYESIAN BELIEF NETWORK MODEL

OPTIMIZED-WATERSHED MANAGEMENT MODEL

ESTUARINE SIMULATION MODEL

MCBCL

Scientific Community

Other DOD installations

Aquatic/Estuarine Module
Coastal Wetlands Module

Monitoring Activities

Hydrodynamics
- Tide gauges
- Groundwater flow rates

Water Chemistry
- Nutrients
- Salinity
- Hydraulic conductivity

Sedimentology
- Organic content
- Particle size

Marsh & Shoreline Delineation
- Distribution
- Elevation
- Tidal benchmarks

Coastal Wetland Research Projects

CW-1: Determine Responses of Marsh Vegetation and Accretion to Relative Surface Elevation
- Monthly marsh sediment accretion rates in fertilized vs. control sites
- Salt-march net primary productivity (NPP)
- Marsh elevations for NRE

CW-2: Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates
- Determine relative impact of wind wave and local wave energy
- Assess sediment accretion/shoreline erosion rates at selected sites
- Evaluate effectiveness of shoreline stabilization structures
- Estimate sediment loading from shoreline erosion

CW-3: Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands
- Water/nutrient flux (2-D flow model)
- Nutrient reactivity of the subsurface (Coupled Water and Salt Mass Balance Model)

OUTCOMES

- Develop user-friendly model to test environmental or management changes to the productivity and sustainability of marshes.
- Develop a map of wetland elevations.
- Develop a GIS tool to assess vulnerability of marshes to stress.
- Report on how amphibious training exercises are affecting sediment accretion and marsh primary productivity.

- Develop shoreline stabilization and protection plan for MCBCL.
- Develop predictive model of estuarine shoreline erosion (NRESE).
- Provide GIS map indicating degree of erosion vulnerability for NRE shoreline.
- Identify site-specific factors influencing erosion in vulnerable areas.

- Determine water exchange of groundwater and tidal water through marshes of the NRE.
- Estimate nutrient exchange between marsh-estuary and marsh-upland boundaries.
- Quantify marsh reactivity with respect to nutrients.
- Determine the contribution of the marsh to mediate NRE water quality via regulation of water fluxes and nutrient transformations.

- Maps and GIS layers of marsh distribution and species composition, elevations, shoreline delineations, and wave energy.
- Digital Elevations Models
- Sea level and tidal amplitude record
COASTAL BARRIER MODULE

MONITORING ACTIVITIES

HYDRODYNAMICS
Wave velocity, wave height/period, currents

MORPHOLOGY
Nearshore bathymetry, island topography, shoreline position

MORPHOLOGY
Texture and composition, sediment compaction and distribution, hard bottom on the shallow seafloor

SEDIMENTOLOGY
Texture and composition, sediment compaction and distribution, hard bottom on the shallow seafloor

BIOLGY
Benthic invertebrates, shorebird/shrewbird, surf fish, dunes/brush, marsh vegetation, sea turtles

MONITORING OUTCOMES

RESEARCH PROJECTS

CB-2: Long-term evolution
Aquatic/Eutelmarine Hydrodynamics Sedimentology
Terrestrial Land Use/Land Cover

CB-1: Short-term Barrier Evolution Related to Stomrs and Land Use
Focus on problem regions (high erosion areas) Initially based on empirical data from field observations
Upgrade to physics-based analytical data

CB-3: Understanding the Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices
Understand abiotic and biotic variables that drive nest success and breeding season distribution
Relate trends in shorebird distribution and nest success to variations in land management and military operations
Understand predator ecology on barrier islands to enhance shorebird conservation

CB-2: Long-term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics
Process seismic and side-scan sonar data
Produce isopach maps of geologic units
Digitize vegetation and shoreline positions
Collect cores and dates from archives of depositional environments

CB-2: Long-term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics

OUTCOMES

MONITORING OUTCOMES

OUTCOMES

OUTCOMES

CB-1: Short-term Barrier Evolution Related to Storms and Land Use
Focus on problem regions (high erosion areas) Initially based on empirical data from field observations
Upgrade to physics-based analytical data

CB-1: Short-term Barrier Evolution Related to Storms and Land Use

CB-2: Long-term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics

OUTCOMES

DEVELOP EFFICIENT MONITORING PROTOCOLS AND CONSERVATION MANAGEMENT PLAN FOR BIRDS
DEVELOP A TOOLKIT OF AVIAN INDICATORS
DEVELOP INDICATOR FOR PREY AVAILABILITY AND PREDATOR DIET
DEVELOP INDEX OF HABITAT VALUE FOR SHOREBIRDS
DETERMINE SURF FISH ABUNDANCE
DETERMINE SIT SELECTION OF SEA TURTLES NESTS AND THEIR HATCHING SUCCESS
DEVELOP INDEX OF HABITAT VALUE FOR SHOREBIRDS

OUTCOMES

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Focus on problem regions (high erosion areas) Initially based on empirical data from field observations
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**TERRESTRIAL MODULE**

**MONITORING ACTIVITIES**
- **LAND COVER/LAND USE**
  - Vegetation types, roads, buildings and military training impacts
- **BIOLOGY**
  - Vegetative community assessment, fuel load
- **SOIL**
  - Bulk density, pH, organic matter content

**RESEARCH PROJECTS**
- **Atmospheric Meteorology**
  - T-1: Effects of Different Understory Restoration Management Options on Terrestrial Structure and Function
    - Restoration techniques (mechanical thinning, herbicide, and mechanical thinning plus herbicide)
    - Seasonality of restoration (growing vs. dormant season)
  - T-2: Effects of Habitat Management for RCWs on bird communities
    - Avian community species abundance and composition
    - RCW foraging habitat quality (upland pine savanna and pine flatwood ecosystems)
    - ID indicator species of high quality habitat

**OUTCOMES**
- **Atmospheric Meteorology**
  - Refine restoration protocols for pine stands that accelerate restoration of herb, insect, and bird communities typical to longleaf pine ecosystems.
  - Develop species indicators of environment and management regime.
  - Develop indicators of habitat quality for RCW and other species.
  - Determine effect of management for RCW on other species at risk.
  - Identify bird species as indicators of high quality pine habitat.
  - Develop GIS database of existing land cover, LIDAR, and topography (NHD-plus).
  - Create database of historic land cover and change beginning in 1980’s.
  - Create land use change analysis for New River watershed.

**MONITORING OUTCOMES**

**OUTCOMES**
- **Monitoring**
  - Indicates inputs from or linkages with other monitoring efforts
- **Research**
  - Indicates inputs from or linkages with other research projects

**LEGEND**

- **Local and State Managers and Other Stakeholders**
- **Scientific Community**
- **Other DOD installations**
- **MCBCL**

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**Terrestrial Module**
**Atmospheric Module**

**Monitoring Activities**

- **Meteorology**
  - Wind speed and direction, relative humidity, temperature, photosynthetically active radiation (PAR), precipitation

- **EPA Criteria Pollutants**
  - Ozone and fine & coarse PM mass

**Research Projects**

**Air-1: Optimization of Prescribed Burning (PB)**
- Retrieve and evaluate continuously monitored on- and off-site data
- Determine emission factors from measured chemical composition of PB smoke for different ecosystems, seasons, burn stages
- Evaluate relationships between measured and forecast fuel conditions, and emissions

**Air-2: Nitrogen Deposition to Terrestrial and Aquatic Ecosystems**
- Wet deposition: Throughfall/Stemflow under representative vegetated canopies
- Dry deposition: Net Throughfall/Stemflow, Canopy Compensation Point model for NH₃ and NO₂ in vegetative canopies

**Outcomes**

- Modified Prioritization Model for improved PB planning and conduct
- Temporally and spatially resolved PB emission factors for a broad spectrum of gaseous & particulate species
- Development and implementation of more accurate smoke generation and dispersion criteria
- Contribution to regional Smoke Management Plan (SMP) development
- Carbon data for assessment of sequestration potential of MCBCL forests

- Accounting for wet deposition of N-species (inorganic and organic) and other nutrients to terrestrial and aquatic ecosystems
- Accounting for wet deposition of N-species (inorganic and organic) to forest floor under vegetative canopies
- Estimate of dry deposition and incorporation of gaseous N-species (NH₃ & NOₓ) into vegetative canopies
- Indirect estimate of the influence of marine aerosols on gaseous N-species (ammonia) deposition

- Establish temporal trends of important air pollutants for MCBCL’s ecosystems
- Identify and understand deviations from more regional trends
- Identify and understand temporal and spatial sensitivities of PB conduct

**Adaptive Monitoring**

**Transition to MCBCL**

**Legend**

- Monitoring
- Research

- Indicates inputs from or linkages with other monitoring efforts
- Indicates inputs from or linkages with other research projects

**Local and State Managers and other Stakeholders**

**Scientific Community**

**Other DOD installations**

**MCBCL**

**Monitoring and Research Projects**

- **Coastal Barrier Meteorology (Ocean)**
- **Terrestrial Land use/Land cover**

**MONITORING ACTIVITIES**

**RESEARCH PROJECTS**

**OUTCOMES**

**MONITORING OUTCOMES**

**TRANSPORT TO MCBCL**

**LEGEND**

- Monitoring
- Research

- Indicates inputs from or linkages with other monitoring efforts
- Indicates inputs from or linkages with other research projects

**Outcomes**

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