Investigation of Water Quality Conditions in the Ashepoo-Combahee-Edisto (ACE) Basin NERR: A GIS Approach

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Recent monitoring has found that portions of the Ashepoo-Combahee-Edisto (ACE) Basin NERR, South Carolina, have higher nutrient levels, lower dissolved oxygen concentrations, and elevated fecal coliform bacteria as compared to the rest of South Carolina's estuarine environments. This finding contrasts the long-held belief that the ACE Basin is a pristine temperate estuary. Studies were conducted to determine the spatial extent and sources of the problems so that targeted management/restoration efforts may be undertaken, particularly as they relate to understanding patterns and drivers of water quality and land use. In July and August of 2008, basic physical water quality parameters, nutrients, chlorophyll-*a* and microbial markers were measured at a random array of 60 stations evenly divided amongst tidal creek (<100m wide) and open water (>100m wide) habitats. Land use data from the Coastal Change Analysis Program (C-CAP, NOAA Coastal Services Center) were geographically intersected with 1000 and 2000m buffers around each station using GIS software. Water quality monitoring efforts confirmed patterns of impaired water quality in several creek systems and highlighted additional systems that showed elevated nutrient and microbial markers. Relatively elevated nutrient concentrations were often accompanied by elevated bacterial indicators, suggesting these share a common source or occur under a common suite of environmental conditions. Elevated levels of these measures were associated with the presence of freshwater and palustrine wetlands and to a lesser extent forested upland. Regression analysis showed total coliforms, total nitrogen, and total phosphorus were positively correlated to distance to St. Helena Sound and negatively related to area of open water and area of marsh and thus landuse as well as physical creek characteristics play an important role in water quality.

INTRODUCTION

During routine monitoring the South Carolina Estuarine and Coastal Assessment Program (SCECAP) documented areas of elevated nutrients and higher fecal coliform concentrations within the ACE Basin compared to other SC estuaries. Water quality, as defined by SCECAP, is rated as good (green), fair (yellow) or poor (red) based on exceedances of state standards or historical data records by a combination of fecal coliform bacteria levels, dissolved oxygen, pH, total nitrogen, total phosphorus, and chlorophyll *a*. The ACE Basin has shown a tendency to have more habitat ranked as fair or poor than the state of South Carolina as a whole (Figure 1), mostly due to high nutrient concentrations, low dissolved oxygen, and elevated fecal coliform concentrations.

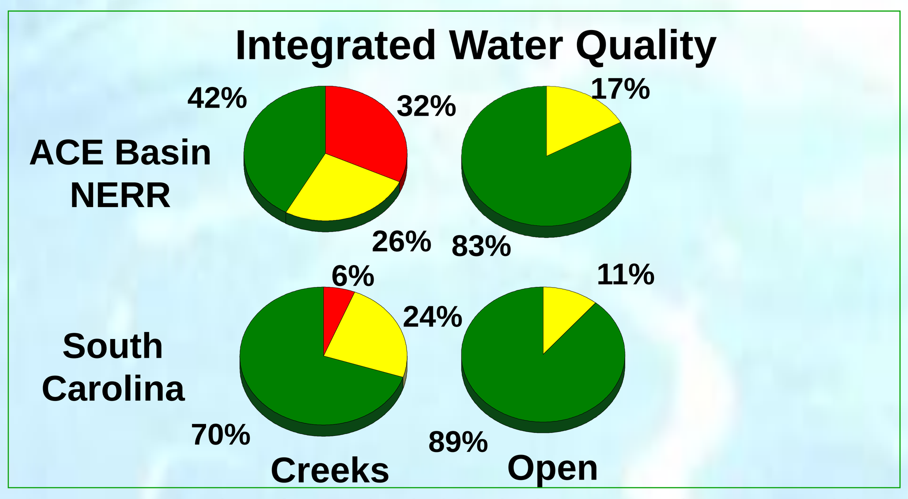


Figure 1. Proportion of estuarine habitat in the ACE Basin NERR and in S.C. as a whole with good, fair, and poor integrated water quality (Bergquist et al 2007).

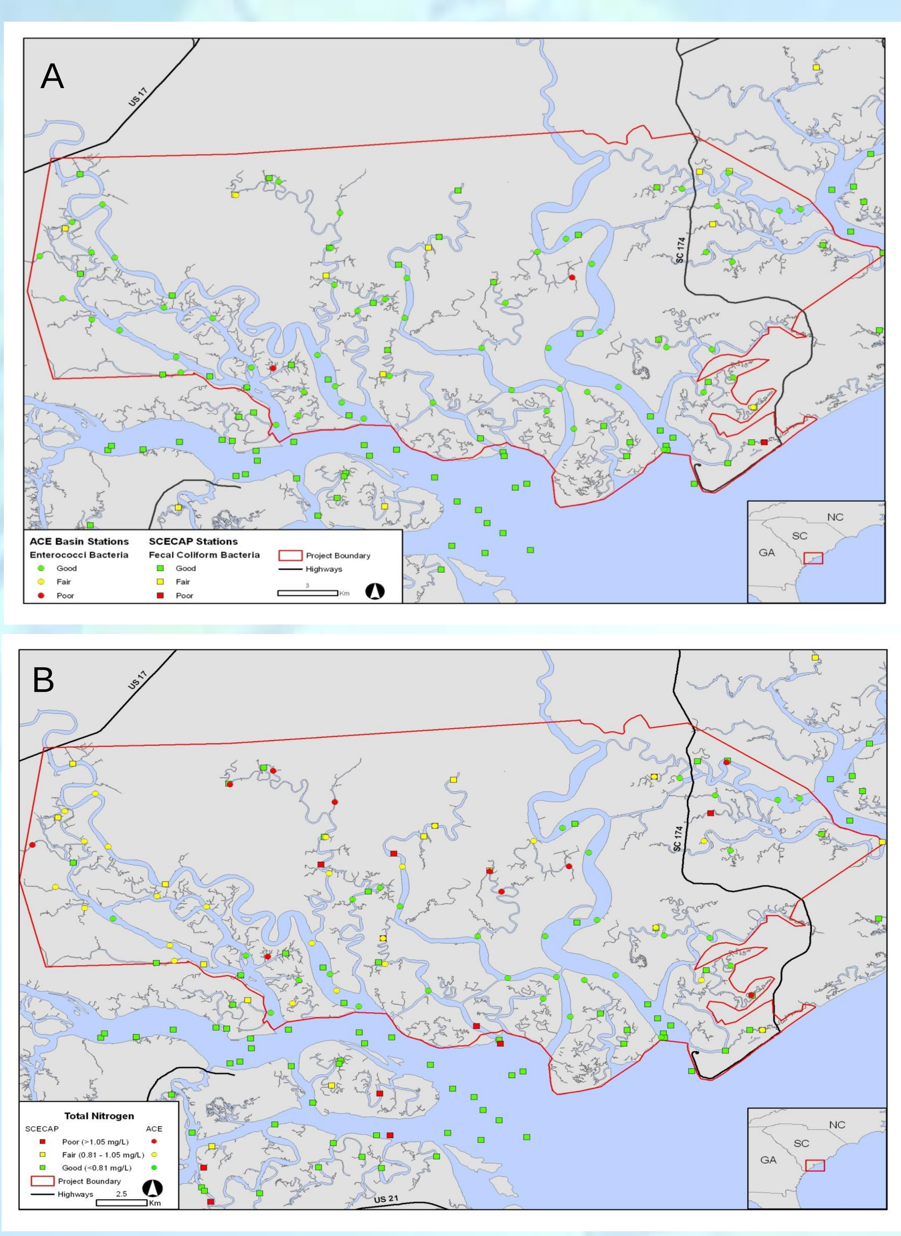
These findings were surprising because the ACE is prized as pristine habitat for conservation, recreation, and eco-tourism. Based on these findings, a study was initiated to better understand the patterns and drivers of water quality in the ACE Basin NERR and to improve water quality through informed management. The study addressed three objectives: (1) confirm the initial patterns of water quality detected by SCECAP and better identify the spatial extent of any problem that exists, (2) identify potential relationships between land cover/land use and water quality within the NERR boundaries, and (3) constrain the potential sources of nutrients and bacterial indicators.

METHODS

This study was performed in two phases. The first phase involved measuring a suite of water quality parameters and determining surrounding land cover/land use at an array of 67 stations (60 randomly selected and seven additional stations within defined creek systems that had been shown to have potential water quality problems from SCECAP monitoring) during a single summer. At each station, standard water quality parameters (temperature, salinity, dissolved oxygen, pH) nutrients (total nitrogen (TN) and phosphorus (TP)), phytoplankton community composition (live screens, lugols fix, chlorophyll *a*), bacterial indicator levels (total coliform, *E. coli*, *Enterococcus*) and several other measures (total and volatile suspended solids ((T/VSS), secchi depth) were quantified. The second phase involved in-depth study of ten creek systems ("target systems") that were defined from the results of Phase I sampling.

In order to define the land cover/use characteristics surrounding each sampling station, a point layer was created in a Geographic Information System (GIS; ESRI ArcGIS 9.3) that included each of the stations visited. 0.5, 0.75, 1, and 2km buffers were then created around each station and the resulting polygon layer was then combined with Coastal Change Analysis Program (C-CAP, NOAA-CSC) land cover/use data using the Intersect tool. The relative percentages of open water, emergent marsh, upland and freshwater/brackish wetland were then calculated for each station. The amount of each upland land cover/use type was also calculated as a percent of total upland. Additional spatial parameters including distance to St. Helena Sound were also defined. Relationships among water quality parameters and surrounding land cover/use area (ha) were examined using correlation analysis, Principle Components Analysis (PCA), and stepwise regression. Multiple regression models were then used to explore the effects of landuse and physical creek characteristics on a subset of water quality parameters. To model the effects of the predictors on water quality, each predictor was entered into the regression equation using its average value for all stations at a 1000m buffer. One predictor at a time was then allowed to vary from its minimum to its maximum.

RESULTS AND DISCUSSION



• The creek systems identified as having relatively elevated nutrient and fecal coliform concentrations in previous studies were confirmed as possessing persistently elevated concentrations during the summer of 2008 (Figure 2).

• Several other creek systems not previously examined within the ACE Basin exhibited signs of elevated nutrients and bacterial indicators.

• Elevated nutrient and bacterial indicator levels tended to occur in the uppermost portions of long and sinuous creek systems.

• Stations with relatively high TN and TP concentrations were often associated with elevated levels of bacterial indicators. Moreover, most water quality parameters were significantly and positively correlated with each other (Table 1), This suggests that these parameters share similar driving factors and/or become elevated under a similar suite of environmental conditions.

Figure 2. Total nitrogen (A) and Enterococcus (B) from the random survey of 60+ stations confirm the pattern of poor water quality in the ACE Basin NERR.

	pH	TN	TP	Chl-a	VSS	Total Coliform
TN	-0.56					
TP	-0.53	0.86				
Chl-a	*-0.22*	0.54	0.59			
VSS	*-0.30*	0.43	0.55	0.33		
Total Coliform	-0.19	0.32	*0.28*	0.42	0.14	
Enterococcus	-0.33	0.50	0.55	0.42	*0.25*	*0.24*

Table 1. Correlation coefficients among a subset of the water quality parameters in the random station array. Italics: $p < 0.10$, Bolded italics: $p < 0.05$, Bolded: $p < 0.01$. Note the negative correlation between all parameters and pH as indicative of a freshwater/upland origin of nutrients and bacterial indicators.

Land Cover Category	Percent of Total Area
Upland	2.1 5.9 9.3 14.5
Freshwater/Brackish Marsh	1.7 3.8 4.3 6.8
Salt Marsh	54.5 56.5 55.4 55.1
Open Water	20.6 20.4 20.5 16.5

Land Cover Category	Percent of Upland Area
Evergreen Forest	22.7 31.2 46.5 53.0
Scrub/Shrub	2.5 6.4 8.5 17.0
Estuarine Scrub/Shrub	0.7 2.2 3.0 3.2
Mixed Forest	0.0 0.7 1.2 2.6
Grassland/ Herbaceous	0.0 0.2 0.8 3.7

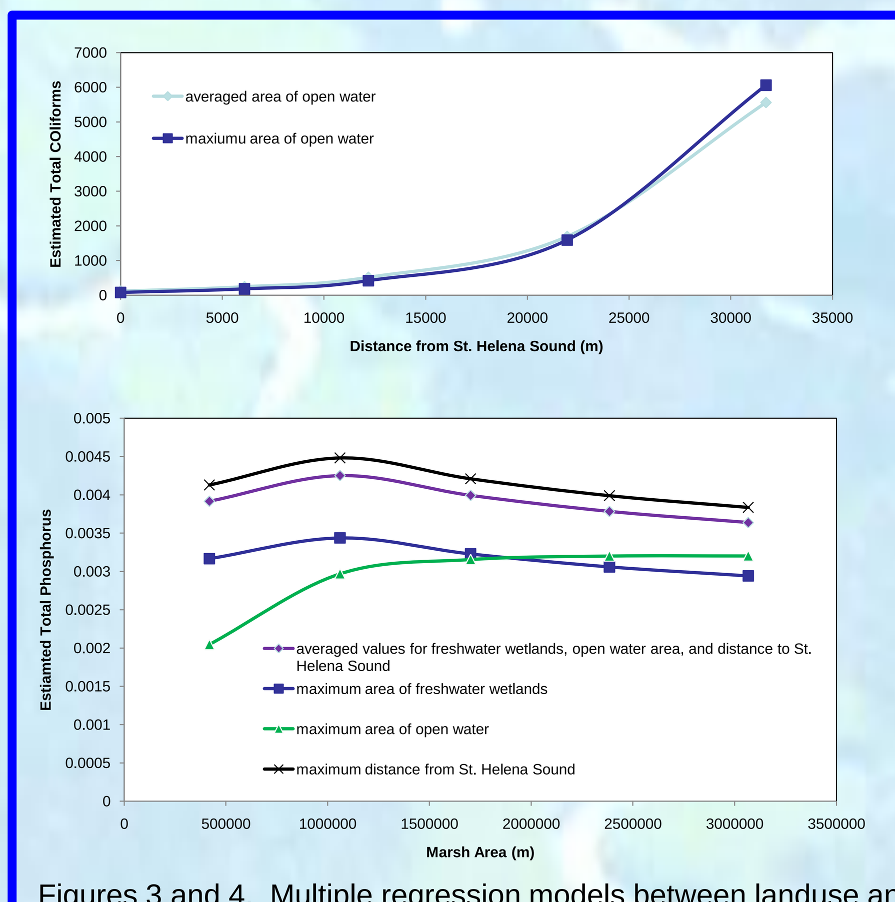
Table 2. Median percent land cover values within 500m(top number), 750m, 1km, and 2km (bottom number) for the random station array. Only most extensive upland land cover categories are shown.

• Land cover/use surrounding the stations sampled for the random array was dominated by salt marsh (~55% of total area), followed by open water and upland (Table 2). Freshwater and brackish marsh (category including managed wetlands) generally accounted for a small percent of total land cover. The upland surrounding these stations was dominated by evergreen forest

• Nutrient and bacterial indicator levels in the random station array were positively, and often significantly, correlated with the proportion of the surrounding area represented by upland and freshwater/brackish marsh and negatively correlated with the amount of surrounding area as open water (data not shown).

• No parameters were significantly correlated with the amount of surrounding salt marsh.

• Of the upland land cover categories, nutrient and bacterial indicator levels were positively, and often significantly, correlated with the amount of upland represented by the various forest types.



Figures 3 and 4. Multiple regression models between landuse and physical creek parameters for total coliforms and total phosphorus (Figures 3 and 4, respectively).

• Multiple regression models showed significantly increased total coliform concentrations as distance to St. Helena Sound increased. This is likely due to increased upstream proximity to source and downstream die-off due to the bactericidal effect of increased salinity (Fig. 3).

• Multiple regression models showed the greatest TP levels associated with the maximum distance to St. Helena Sound (Fig. 4) and lower marsh cover. Open water had a strong dilution effect on TP concentrations

• In general, regression analysis showed total coliforms, total nitrogen, and total phosphorus were positively correlated to distance to St. Helena Sound and negatively related to area of open water and area of marsh. Thus, dilution capacity and the ability of a particular water body to exchange with the ocean plays a major role in localized water quality.

Conclusions

• This study confirmed relatively elevated nutrient and bacterial indicator concentrations in several creek systems and identified several other systems with similar patterns in the northern ACE Basin.

• Relatively elevated nutrient concentrations were often accompanied by elevated bacterial indicators, suggesting these share a common source or occur under a common suite of environmental conditions.

• Elevated levels of these measures were associated with the presence of freshwater/brackish wetlands and to a lesser extent forested upland. Inputs from upland and freshwater/brackish marsh interact with physical creek characteristics such distance from open water and dilution/flushing capacity to produce the observed water quality variability.

Ongoing Studies

• **Specific Nutrient Species:** Current investigations into the forms of nutrients (N, P) most likely entering these systems and their distributions within and among creek systems are underway.
• **Nutrient utilization studies:** Investigations as to the trophic status and degree of nutrient limitation of select creek systems are ongoing to evaluate the role of nutrients in primary productivity.
• **Stable Carbon and Nitrogen Isotopes:** These analyses will help identify the sources (wetlands, forest, salt marsh, etc) of the organic material found in the creek systems.

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Literature Cited: Bergquist, D.C, Crowe, S., Felber, J., Van Dolah, R., Chestnut, D. 2007. Monitoring Program for assessing Habitat Quality of Estuarine Systems: Application to the ACE Basin National Estuarine Research Reserve. Poster Presentation. NERRS Conference, Fall 2007.