South Carolina Water Resources Research Institute
Annual Technical Report
FY 2006

Introduction

The highlight of the past year for the South Carolina Water Resources Center has been the completion of work on a multi-year watershed assessment for the Saluda-Reedy Watershed Consortium. The consortium is a collaborative effort by organizations and individuals concerned about the impacts of changing land-use on the purity and abundance of water in the Saluda-Reedy basin. Some of the work completed by the Water Center is described below.

Land Cover Change

With rapid changes in land use/land cover occurring across the U.S., remote sensing technology is an essential tool in monitoring urban development and environmental conditions. Using satellite imagery for land cover change detection is possible because changes in light and energy reflectance values that are monitored by the satellite can be translated to changes in land cover categories. Techniques to perform change detection with satellite imagery have become numerous because of increasing versatility in manipulating digital data and increasing computing power.

From a strategic perspective, using satellite multispectral imagery such as Landsat Thematic Mapper, offers timely monitoring methods for extensive land areas. The analysis goal is to characterize those areas of important change (e.g. forest clearing or urban land development) between two or more image dates. This project used a process called unsupervised classification analysis. In this process the computer groups similar reflectance values into numerous classes and the scientist uses samples of aerial photography and other geographic data to define the final classes that are used (eg. developed land, forest land, farm land). Specifically, the imagery was used to derive three classes of forest (deciduous, evergreen and mixed) and then determine the different amounts of those categories in imagery from 1985 and 2000.

Numerous research groups at universities, federal and state agencies use this type of satellite image analysis methodology to produce land cover maps. In the 1990's the U.S. Fish and Wildlife Service contracted with numerous states to produce land cover maps as part of a nation-wide habitat study. Recently, the U.S. Geological Survey and the U.S. Environmental Protection Agency teamed with other federal agencies to produce the Multi-Resolution Land Cover (MRLC) data set for the entire U.S. The Clemson researchers followed that same methodology to produce the land cover data set for upstate South Carolina.

Quantifying and analyzing impervious surfaces is an important step for determining the current state of a watershed. It can serve as a key ingredient to carry out further research for determining land-use planning implications and directing future decision-making processes for ecologically sensitive zones. This study has provided impervious cover datasets for the South Carolina Water Resource Center, which is currently conducting research as a part of the Saluda Reedy Watershed Consortium.

Urban Growth Modeling

Information from the satellite imagery studies was used as a basis for an urban growth projection model developed for the Saluda Reedy Watershed as well as surrounding counties. The model predicts urban land development to increase at a rate five times higher than population growth if no significant policy interventions are made. Growth of this type has serious implications for water quality in the two rivers as well as for the provision of drinking water to counties in the Upstate of South Carolina.

Watershed Education

In conjunction with a scientific assessment of the Saluda and Reedy River watershed, including projects that have been funded through the USGS WRRI program and the South Carolina Water Resources Center, the watershed education program was established to help school children and stakeholders understand processes shaping the Reedy River from its source to its end in Lake Greenwood. A Discover Carolina program has been established at Lake Greenwood State Recreation Area's Drummond Center with the assistance of the SCWRC Watershed Education Coordinator. Two curriculum units were developed that focus on Lake Greenwood's aquatic ecology and watershed. Through a partnership with SC Life/Clemson University, a teacher training course was offered: Teaching Your Watershed at the park to test the curriculum. Several teachers took the course for credit,. All were excited about the program and incorporating watershed education. Those teachers will be bringing their class to the park to do the program and some are hoping to do a whole curriculum unit this year on Lake Greenwood.

Research Program

Projects currently underway:

A Statewide Biomarker Approach to Investigate Pollution Effects on Sunfish (Lepomis sp.) in Wadeable Streams of South Carolina. Funding Agency: USGS/SC Water Resources Center. PI: Dr. Peter van den Hurk--Clemson University.

A Statewide Sediment and Water Quality Approach to Characterize Pollution in Wadeable Streams of South Carolina--Phase 2. Funding Agency: USGS/SC Water Resources Center. PI: Dr. Elizabeth R. Carraway.

The Saluda and Reedy River Watershed Land Use and Water Quality Assessment. Funding Agency: V. Kann Rasmussen Foundation. Partners: Mulitdisciplinary effort at Clemson University, Lander University and Furman University.

GIS-based Database Management and Spatial Modeling for Coastal Ecosystems. Funding Agency: South Carolina Sea Grant LU-CES Program/NOAA. Partners: University of South Carolina, NOAA NOS Southeast Fisheries Center.

The NY State Wetland Monitoring System: A Remote Sensing Assessment. Funding Agency: US Environmental Protection Agency. Partners: SUNY--Albany.

Forest Fuel Load Classification Using Hyperspectral Image Analysis. Funding Agency: USDA-US Forest Service. Partners: Spectro Tech, Inc.

A Statewide Sediment and Water Quality Approach to Characterize Pollution in Wadeable Streams of South Carolina

Basic Information

Title:	A Statewide Sediment and Water Quality Approach to Characterize Pollution in Wadeable Streams of South Carolina
Project Number:	2006SC29B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	Third
Research Category:	Not Applicable
Focus Category:	Water Quality, Sediments, Surface Water
Descriptors:	None
Principal Investigators:	Elizabeth R. Carraway, Stephen Klaine, Marc C. Scott

Publication

1. Jones, AJ, Carraway, ER, Klaine, SJ, Scott, MC. (2007). A statewide sediment and water quality approach to characterize pollution in wadeable streams of South Carolina. Poster presented at the joint Carolinas and Southeastern Regional Meeting of the Society of Environmental Toxicology and Chemistry, Athens, GA, April 11-13.

Progress Report

for

A Statewide Sediment and Water Quality Approach to Characterize Pollution in Wadeable Streams of South Carolina

Elizabeth R. Carraway

In the period March 1, 2006 to February 28, 2007 water and sediment samples for the analysis of organic and metal contaminants were obtained during the over the spring to fall period. Finding suitable and accessible sampling sites as close as possible to the target sites (i.e., those sites selected randomly within certain watershed parameters to result in an appropriately random sampling plan) was more challenging than anticipated and overall approximately 70 sites were sampled rather than the goal of 100. Water samples were treated as proposed for selected organic contaminants and water and sediment samples were analysed for several metal contaminants. The organic analytes that were specifically targeted are: 17□-ethynlestradiol, 4-nonylphenol, caffeine, triclosan, meclofenamic acid, atrazine, pyrene, benzo(a)pyrene, phenanthrene, anthracene, perylene, PCB-30, and PCB-204. They cover a range of compounds that can be found in surface waters resulting from various anthropogenic sources such as pharmaceuticals, personal care products, pesticides, and combustion. In the samples from this season, these compounds were not found (or are present at concentrations below detection limits), however, hydrocarbons that are characteristic of fuels (gasoline, diesel) were found. Recently, the Environmental Engineering and Science department purchased a new GC-MS and we are working on translating and optimizing our method on that instrument. Detection limits should be much lower on this new instrument. For metals analysis, ten metals were measured by ICP-MS: chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), silver

(Ag), cadmium (Cd), thallium (Tl), and lead (Pb). Total aqueous mercury has been measured by CVAAS. ICP-MS results indicate that a small number of sites exceed the USEPA constant contamination concentration and contaminant maximum concentration for waterborne cadmium, copper and nickel. All mercury concentrations have been below detection limits. At this point, the overall results support generally good water quality for small, wadeable streams in South Carolina with the exception of a few exceedances for Cd, Cu, and Ni. This may imply that for a typical small watershed, pollutant concentrations remain very low with higher levels observed in watersheds of greater scale where more and larger municipalities contribute runoff and effluents to surface streams.

A Statewide Biomarker Approach to Investigate Pollution Effects on fish in Wadeable Streams of South Carolina

Basic Information

Title:	A Statewide Biomarker Approach to Investigate Pollution Effects on fish in Wadeable Streams of South Carolina
Project Number:	2006SC30B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	Third
Research Category:	Not Applicable
Focus Category:	Water Quality, Toxic Substances, Surface Water
Descriptors:	
Principal Investigators:	Peter Van Den Hurk, Stephen Klaine, Aaron Roberts, Marc C. Scott

Publication

Progress Report

June 2007

A statewide biomarker approach to investigate pollution effects on fish in wadeable streams of South Carolina.

Peter van den Hurk[1], Molly E. Keaton[1], Stephen J. Klaine[1], Marc C. Scott[2]

Sponsored by:

SOUTH CAROLINA WATER RESOURCES CENTER

SOUTH CAROLINA COMPETITIVE GRANTS PROGRAM

[1] Department of Biological Sciences, Institute of Environmental Toxicology, Clemson University, 237 Long Hall, Clemson, SC 29634 [2] South Carolina Department of Natural Resources

Executive summary

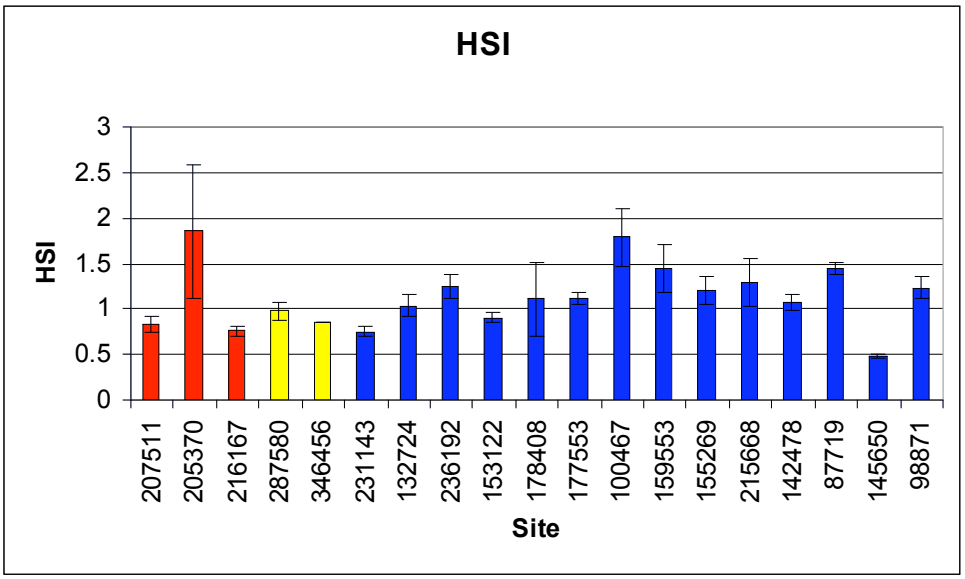
The numbers of freshwater species in South Carolina have been under pressure for many years. However, the threats that these organisms face from point and non-point source pollution is largely unknown. In May 2006 the South Carolina Department of Natural Resources (SCDNR) began a five year survey to establish the species richness and abundance of fish species in the wadeable streams of South Carolina. In addition to the fish population parameters, one of the goals of this study is to use molecular biomarkers of contaminant exposure to assess the health of fish populations in South Carolina's freshwater streams. Another objective of the project is to correlate the biomarker responses with fish population parameters and with land use data from the sampled watersheds.

During the first year of the study (2006), sunfish (*Lepomis* sp.) were sampled from May through September 2006 at randomly selected sites in three ecobasins in South Carolina (the Saluda Sandhills, the Savannah Sandhills, and the Pee Dee Atlantic Southern Loam Plains). Somatic indices, including hepatosomatic index (HSI), spleen somatic index (SSI), gonadosomatic index (GSI), and Fulton's condition factor (K) were measured to determine the overall physiological condition of the fish. Cytochrome p4501A induction (as measured by the EROD assay) and bile fluorescence were measured to estimate exposure to polycyclic aromatic hydrocarbons (PAHs). Glutathione-s-transferase (GST) was measured to estimate oxidative stress. Additionally, measurements of land use and fish assemblage structure were obtained by SCDNR.

The results indicate that the somatic indices (HSI, SSI, and GSI) were influenced by several factors, including sex, season, and probably by the presence of parasitic infections (Figures 1-4). Of the biomarkers, both EROD and GST were generally not induced beyond basal levels for the collected species (Figures 5, 6, 7). However, bile fluorescence was significantly elevated at specific sites within the Saluda Sandhills and Pee Dee Atlantic Southern Loam Plains, indicating transient exposure and metabolism to PAHs at these sites (Figure 8, 9,10). These ecobasins also had overall higher EROD activities, bile fluorescence, and HSIs than the Savannah Sandhills, again indicating that fish from these ecobasins are possibly exposed to higher levels of PAHs than specimens from the Savannah Sandhills.

Additionally, bile fluorescence and HSI were significantly correlated with the percentage of developed land and impervious surface cover within the watershed area at sites, indicating a possible link between PAH exposure and land use. This study provides a first estimate of the health of fish in specific ecobasins of South Carolina. As SCDNR's survey of wadeable streams continues for the next four years, a more complete assessment of the ecological health of the fish in South Carolina will be provided.

Figure 1. HSI by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



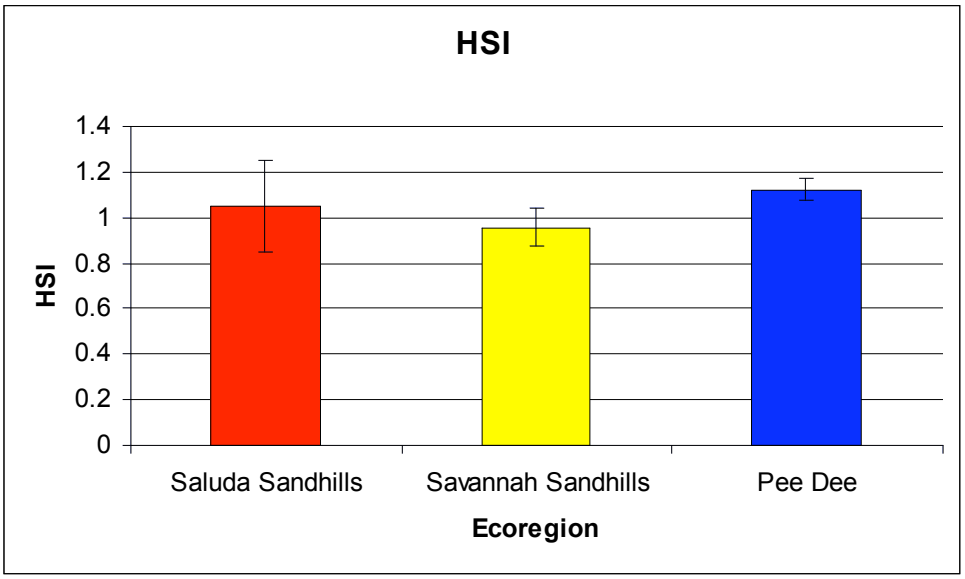
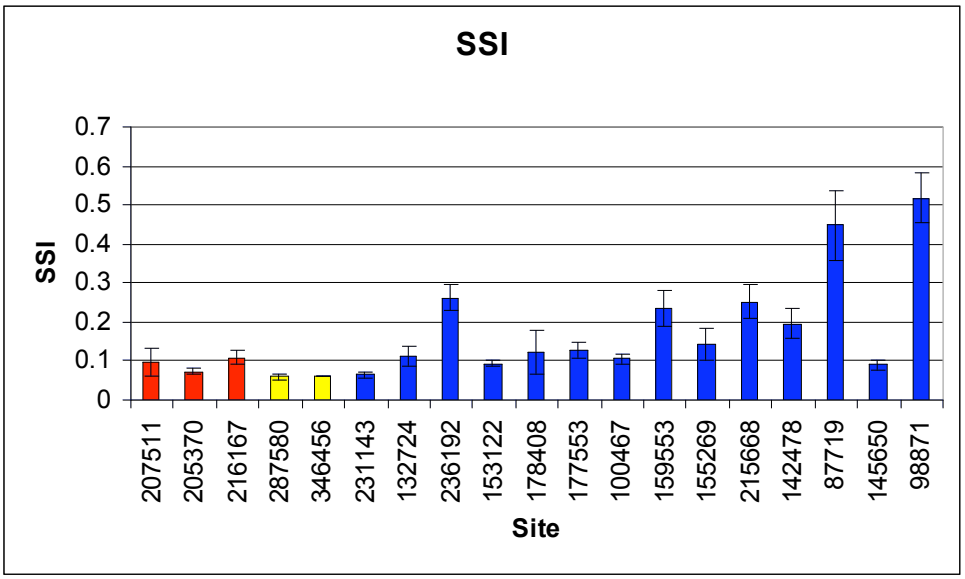


Figure 2. SSI by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



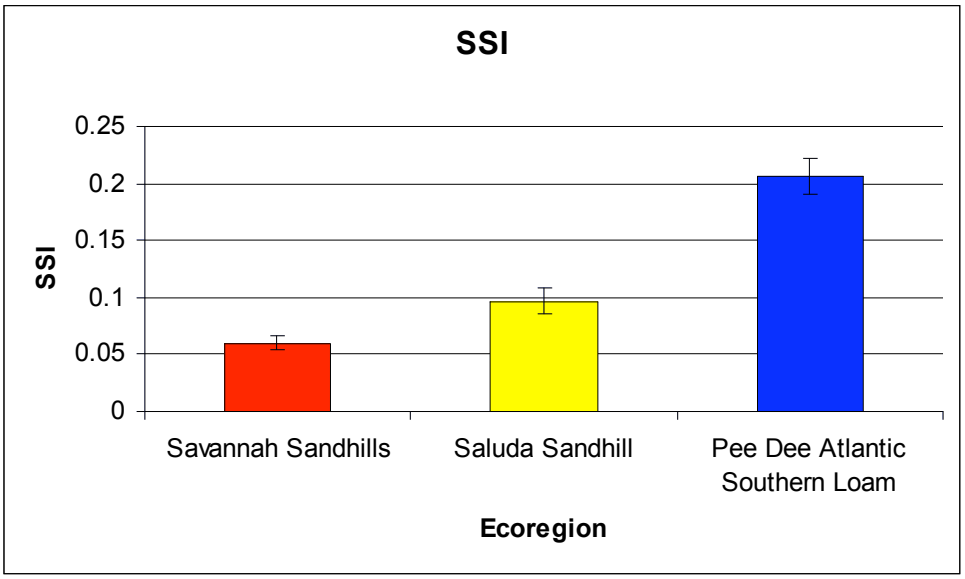
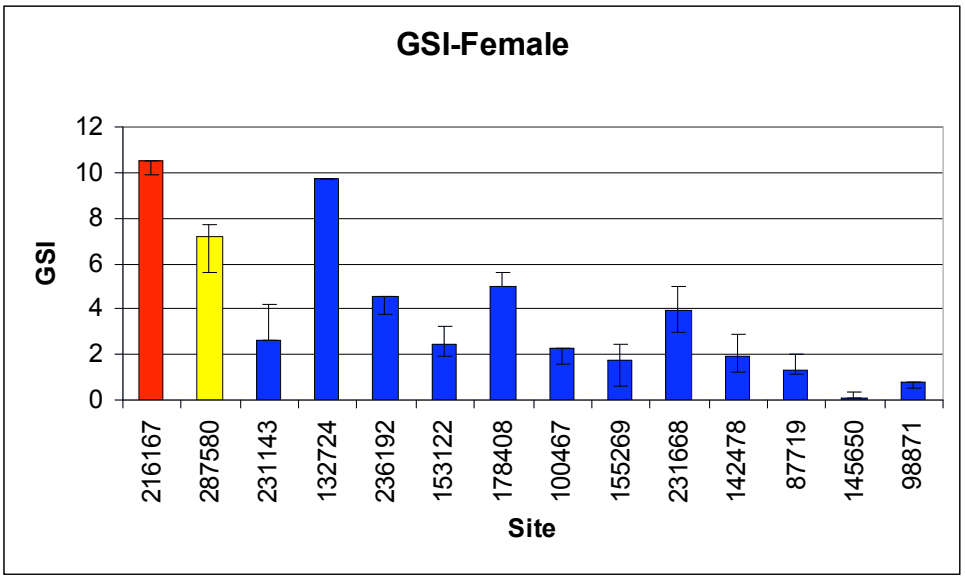


Figure 3. GSI female fish by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



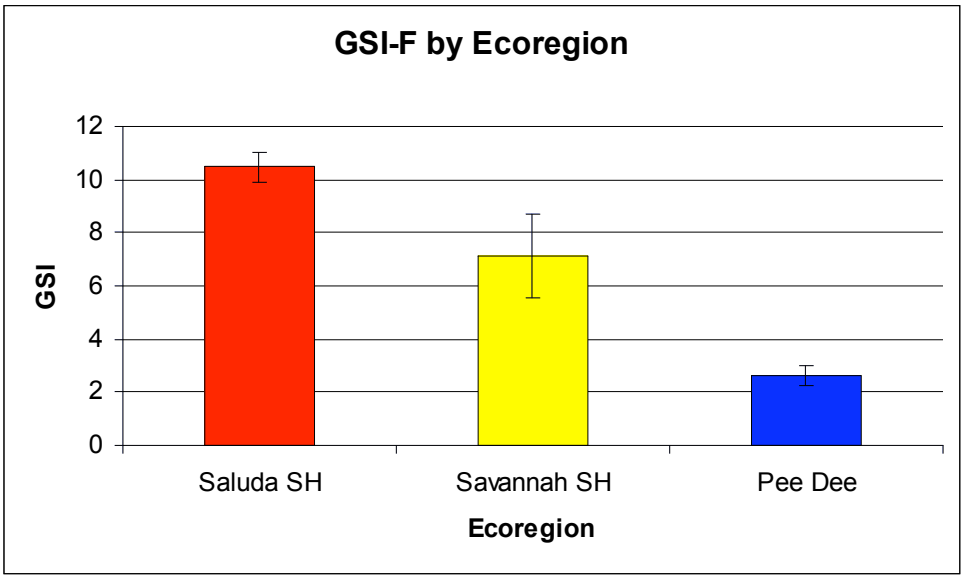
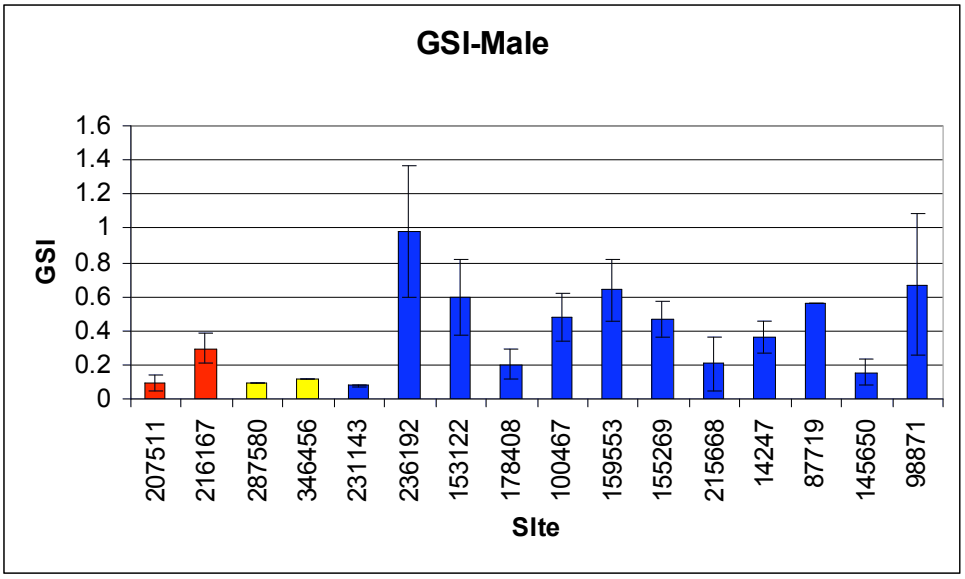


Figure 4. GSI male fish by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



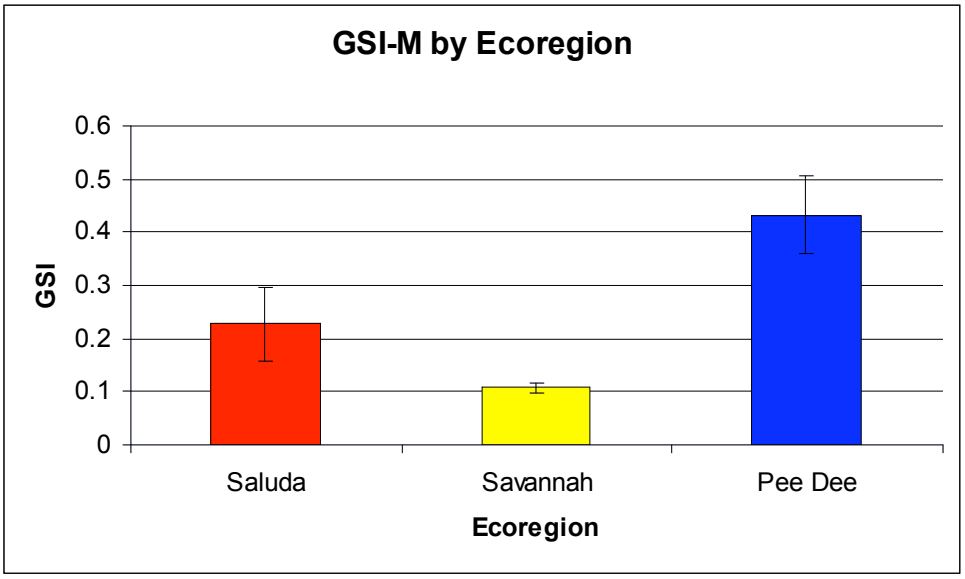
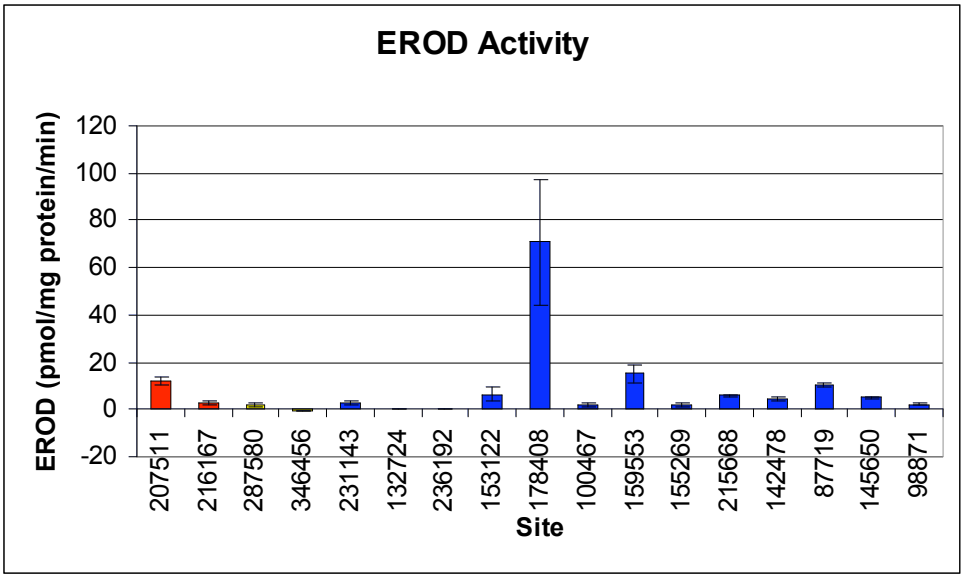


Figure 5. EROD activity by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



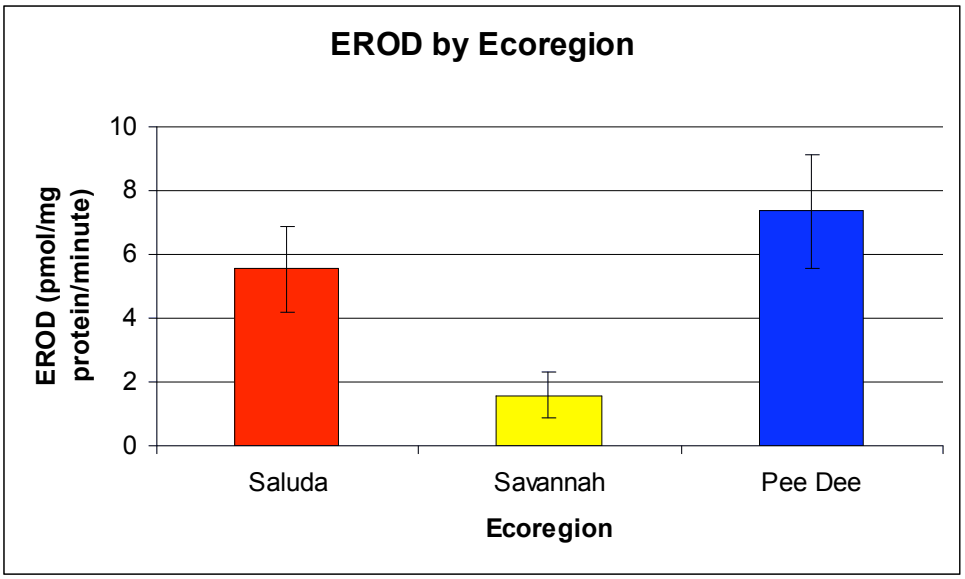
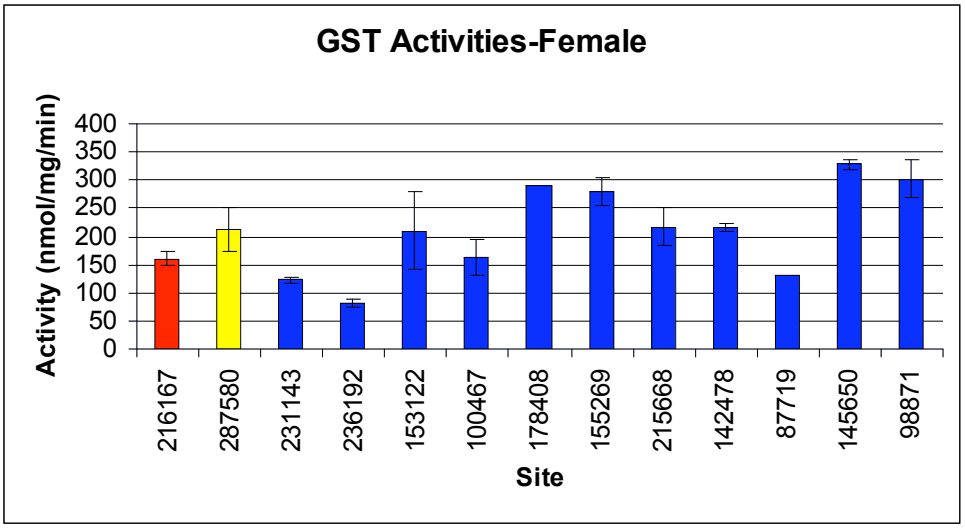


Figure 6. GST activities in female fish by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



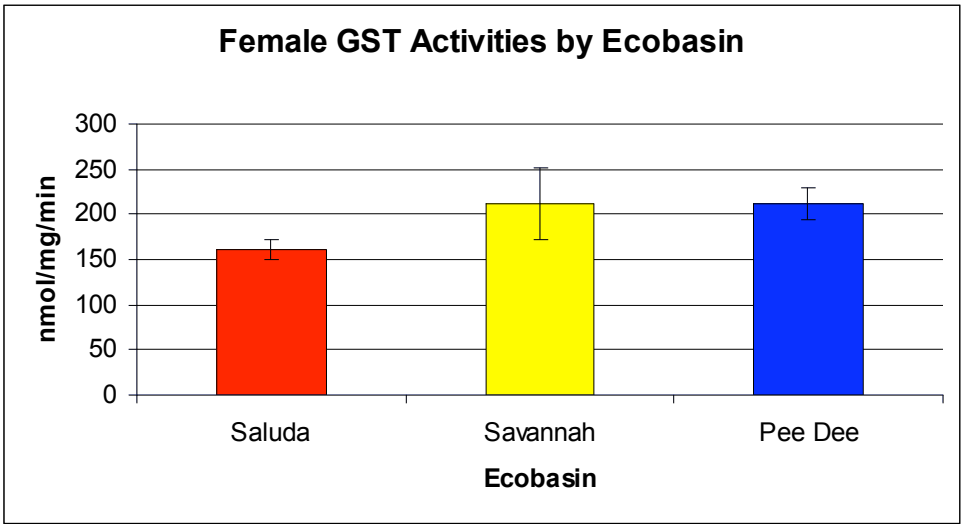
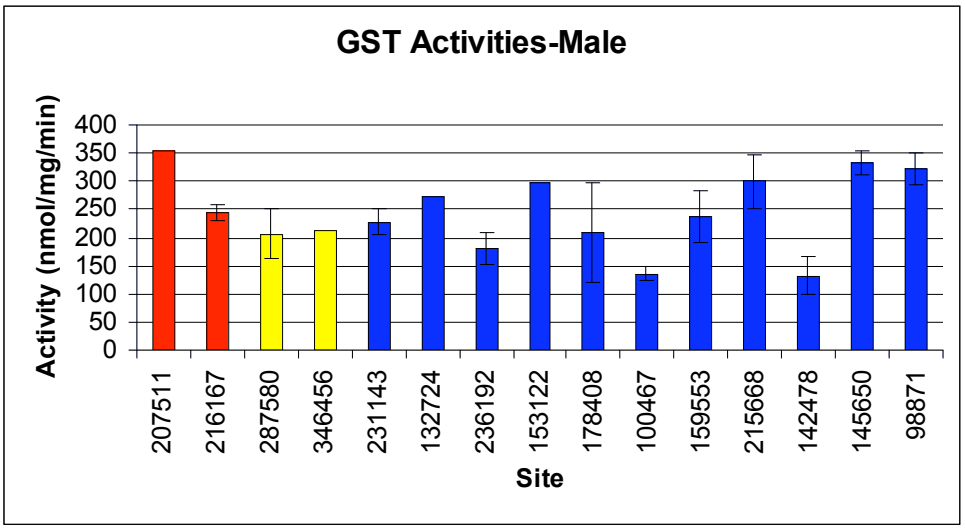


Figure 7. GST activities in male fish by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



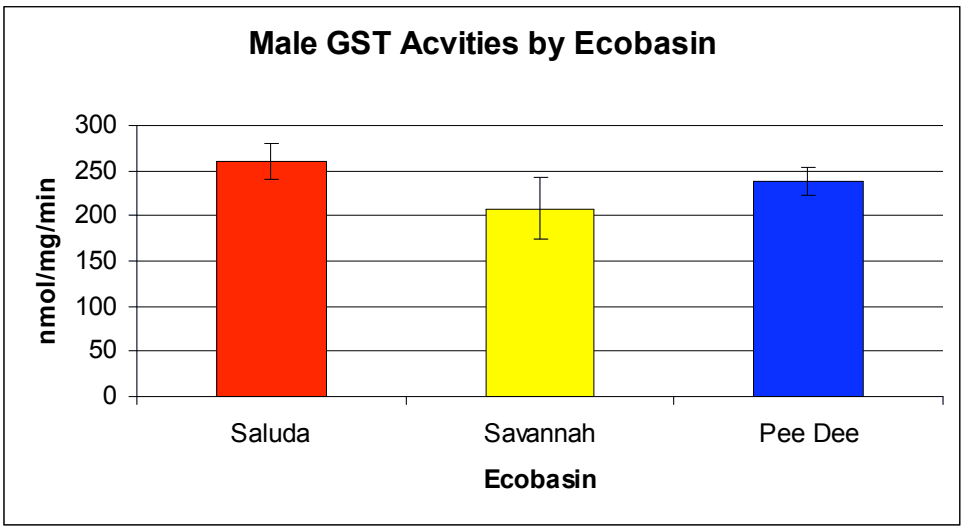
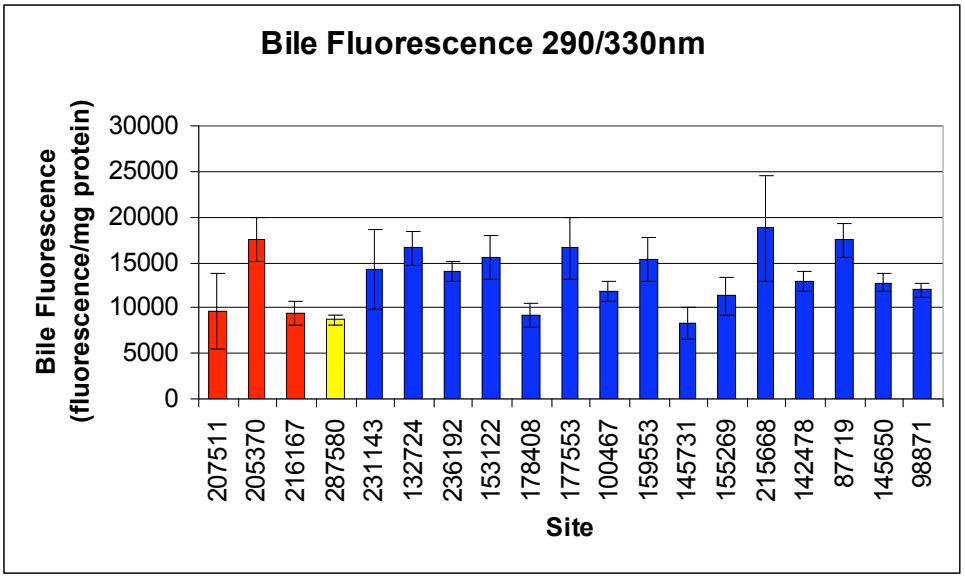


Figure 8. Bile Fluorescence at wavelength 290/330nm by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



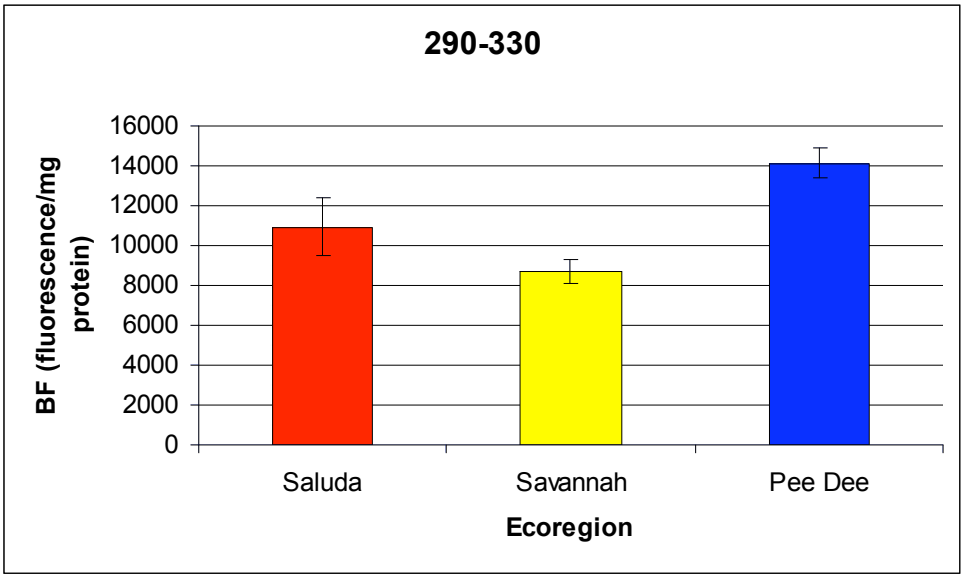
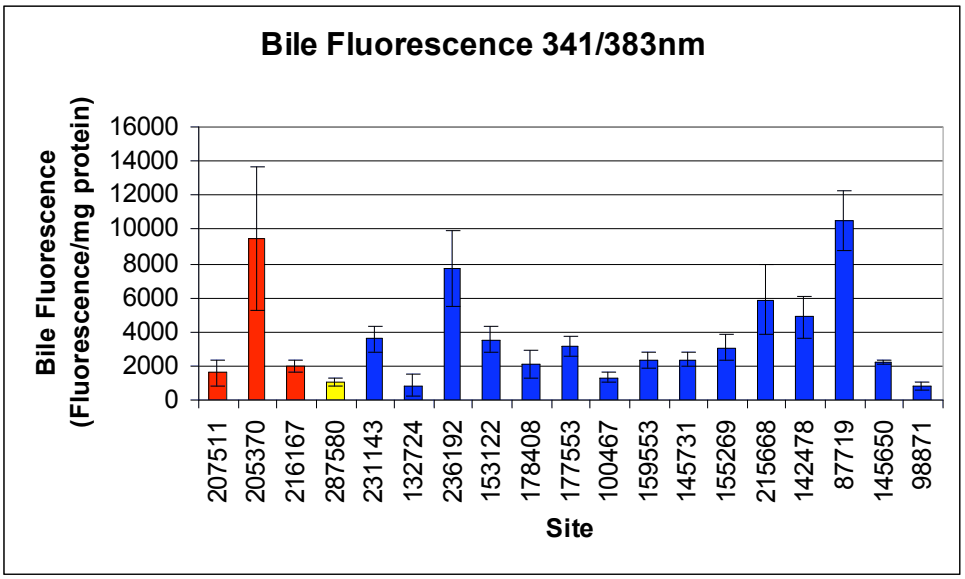


Figure 9. Bile Fluorescence at wavelength 341/381nm by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.



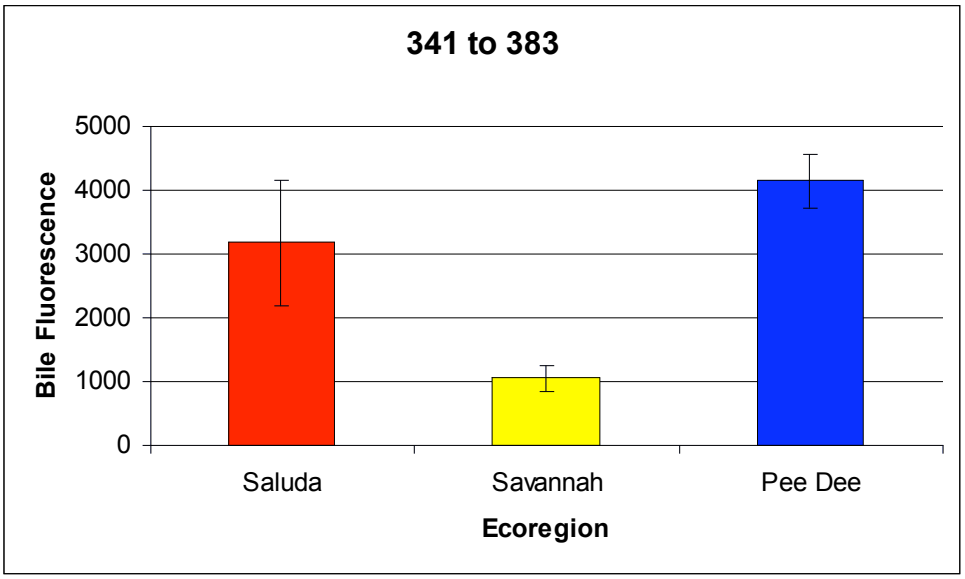
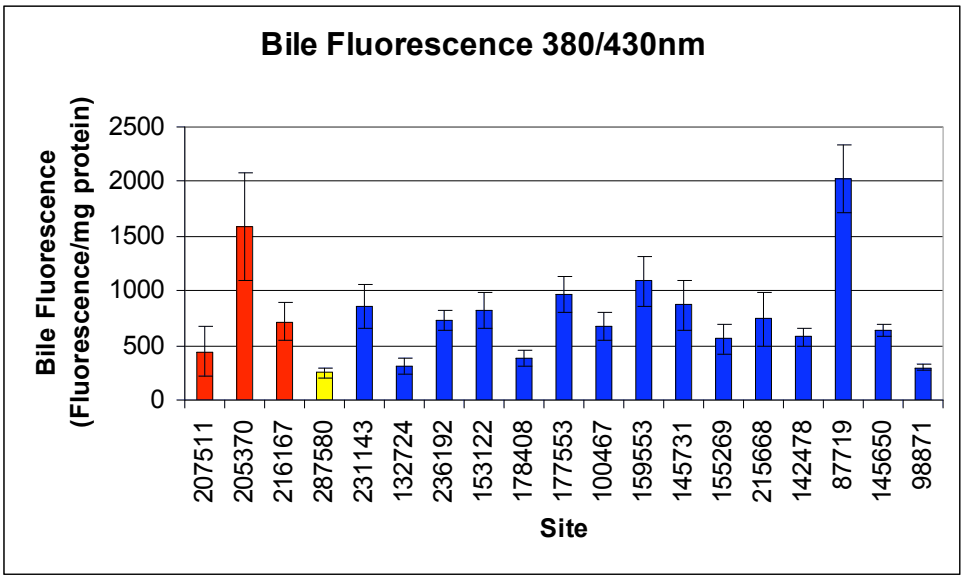
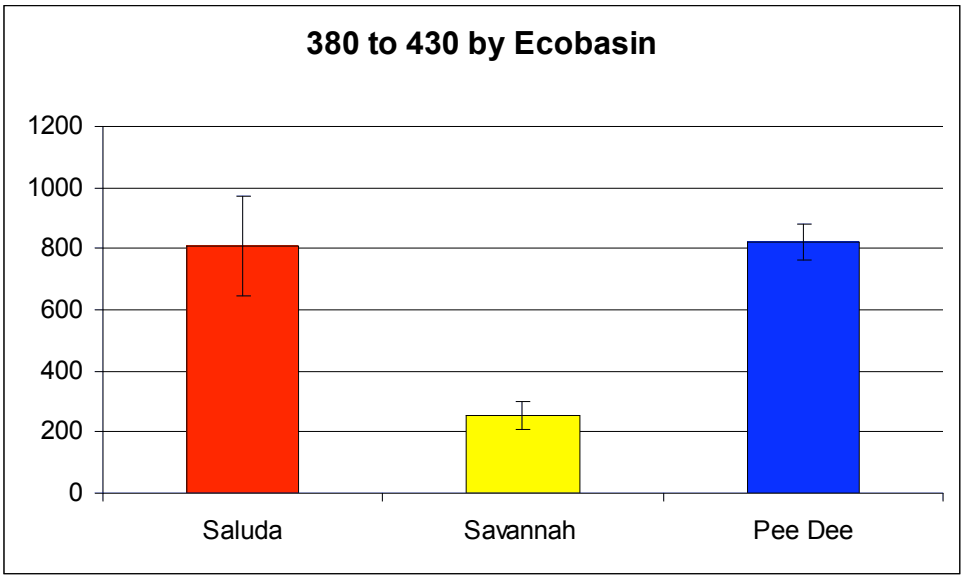


Figure 10. Bile Fluorescence at wavelength 380/430nm by site and ecobasin. Red represents Saluda Sandhills. Yellow represents Savannah Sandhills. Blue represents PDALSP.





Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	4	0	0	0	4
Ph.D.	1	0	0	3	4
Post-Doc.	0	0	0	0	0
Total	5	0	0	3	8

Notable Awards and Achievements

University of Delaware Invited to UD and provided a workshop for faculty and administrators on urban growth modeling and potential affects of urban growth on receiving waters.

SUNY Albany Invited to SUNY and provided a workshop on sustainable growth, local policy and environmental protection for small municipalities.

SC Sea Grant Invited to three South Carolina coastal communities to provide information on coastal growth, potential environmental impacts from that growth and potential policy implications at the local, state and federal levels.

Mott Foundation Met with members of the Mott Foundation in Ann Arbor, Michigan to determine possible avenues of collaboration concerning aging dams in the Southeast and potential chemical contamination in impoundments.

U.S. Forest Service Invited to present information to a national USFS short course concerning urbanization and impacts to forests and other natural resources.

Clemson University Water Forum Co-hosted an educational forum for administrators, faculty and students in order to build a more cohesive network of water research on campus.

Leadership South Carolina Invited to address group on a broad range of natural resource and water issues facing South Carolina in the upcoming decades.

Catawba River Basin Commission Invited to address the Commission on work of the SCWRC and how the Center might assist the Commission as it works toward settling issues between SC and NC.

State Mapping Advisory Committee Invited to make a presentation at the annual meeting regarding using GIS and computer mapping technologies toward solving problems related to natural resource and water management.

Publications from Prior Projects

1. 1996SC101B ("Assessment of the Effect of Bioturbation on Advective Contaminant Exchange at the Sediment Stream Interface") - Water Resources Research Institute Reports - "Assessment of the Effect of Bioturbation on Advective Contaminant Exchange at the Sediment Stream Interface" - Water Resources Research Institute Reports - Work, Paul A., Paul Moore, John McEnery and D.D. Reible. 1999. Assessment of the Effect of Bitrubation on Advective Contaminant Exchange at the Sediment Stream Interface. South Carolina Water Resource Center, Clemson University, Clemson, SC 180 pages.
2. 1996SC101B ("Assessment of the Effect of Bioturbation on Advective Contaminant Exchange at teh Sediment Stream Interface") - Dissertations - Moore, Paul Roland. 1999. Bioturbation and Pore Waer Exchange in a Laboratory Flume. MS Dissertation, Civil Engineering, Clemson University, Clemson, SC, 165 pages.
3. 1996SC101B ("Assessment of the Effect of Bioturbation on Advective Contaminant Exchange at the Sediment Stream Interface") - Dissertations - McEnery, John Anthony. 2000. Interstitial Pore Water Flux through Streambeds of Varying Composition, Ph.D. Dissertation. Civil Engineering, Clemson University, Clemson, SC, 172 pages.
4. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompased by the Savannah River Watershed Region: Policy Projections for the Future") - Water Resources Research Institute Reports - Backman, Kenneth F. and Sheila J. Backman. 2000. Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region. South Carolina Water Resources Center, Clemson University, Clemson, SC, 35 pages.
5. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompased by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Backman, Sheila J. and Kenneth F. Backman. 2001. Perceptions of Water Quality in the Five Lake Savannah Watershed Region. In College of Health, Education and Human Development Faculty Research Forum, Clemson University, Clemson, SC, p. 3.
6. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Davis, Jason and Kenneth F. Backman. 2001. Boaters and Marine Operators Perceptions of Water Quality in the Five Lake Savannah Watershed Region. In Southeastern Recreation Research Conference, Asheville, NC, February 21-23.
7. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Davis, Jason and Kenneth F. Backman. 2001. Boaters and Marine Operators Perceptions of Water Quality in the Five Lake Savannah Watershed Region. In Southeastern Recreation Research Conference, Asheville, NC, February 21-23.
8. 2000SC1B ("Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region: Policy Projections for the Future") - Conference Proceedings - Walker, Joseph and Kenneth F. Backman. 2001. Exploring the Effect of Trip Distance on Boaters Perception of Water Quality. In Southeastern Recreation Research Conference, Asheville, NC, February 21-23.
9. 2000SC44B ("Initiating Effective Algae Reduction on Lake Greenwood, South Carolina") - Conference Proceedings - Blacklocke, Sean. 1999. Regulating Animal Agriculture in America: Who Benefits? In 80th Annual Conference of the American Farm Bureau Federation, Albuquerque, NM. 9.

2000SC44B ("Initiating Effective Algae Reduction on Lake Greenwood, South Carolina") - Conference Proceedings - Blacklocke, Sean. 1999. An Inquiry into the Rationale for Prioritizing South Carolinas Animal Feeding Operations for Water Pollution Regulation. In 1st Annual South Carolina Water and Environmental Symposium, University of South Carolina, Columbia, SC

10. 2000SC44B ("Initiating Effective Algae Reduction on Lake Greenwood, South Carolina") - Conference Proceedings - Blacklocke, Sean. 1999. An Inquiry into the Rationale for Prioritizing South Carolinas Animal Feeding Operations for Water Pollution Regulation. In 1st Annual South Carolina Water and Environmental Symposium, University of South Carolina, Columbia, SC.
11. 2000SC3B ("Restablishment of an Estuarine Marsh and Waterway after Causeway Removal") - Water Resources Research Institute Reports - Curran, Mary Carla, Randall Cross and Earl J. Hayter. 2001. Reestablishment of an Estuarine Marsh and Waterway after Causeway Removal. South Carolina Water Resources Center. Clemson University, Clemson, South Carolina, 11 pages.
12. 2001SC3781B ("Reservoir Shoreline Erosion and Sediment Deposition with Cohesive Sediments") - Water Resources Research Institute Reports - Elci, Sebnem and Paul A. Work. 2002. Prediction of Shoreline Erosion and Sedimentation in Hartwell Lake, SC/GA, Georgia Tech Regional Engineering Program Civil and Environmental Engineering, Report No. GTREP-CEE/2002-1, South Carolina Water Resources Center, Clemson University, Clemson, South Carolina, 97 pages.
13. 2001SC3761B ("Using Spatial Techniques to Assess the Contribution of Animal Agriculture on Watershed Impariment for the Saluda River Watershed in South Carolina") - Water Resources Research Institute Reports - Lu, Kang S. and Jeffery S. Allen. 2001. Animal Agriculture and Watershed Impairment in South Carolina. South Carolina Water Resources Center, Clemson University, Clemson, SC, 69 pages.
14. 2002SC1B ("Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina") - Conference Proceedings - Lu, Kang S. and Jeffery S. Allen. 2003. Animal Agriculture and Watershed Impairment in South Carolina: A GIS-based spatial assessment. In Ninth International Symposium on Animal, Agriculture and Food Processing Waste (ISAAFPW 2003), Durham, NC.
15. 2002SC1B ("Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina") - Other Publications - Allen, Jeffery S. and Kang S. Lu. 2002 Animal Agriculture and Watershed Impairment in South Carolina. Report submitted to PSA Agrisystems Productivity and Profitability Competitive Grants Program.
16. 2002SC1B ("Using Remote Sensing and GIS Technology to Assess the Relationship of Land Cover to Watershed Impairment for the Saluda River Basin South Carolina") - Other Publications - Allen, Jeffery S. and Kang S. Lu. 2002. Modeling and Predicting Future Urban Growth in the Charleston, South Carolina Area. Special issue of Conservation Ecology, {on-line} URL: http:/www.consecol.org/vol8/iss2/art2.
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