South Carolina Water Resources Research Institute
Annual Technical Report
FY 2013

Introduction

The South Carolina Water Resources Center uses its operating funds to carry out its mission as a liaison between the US Geological Survey, the university community and the water resources constituencies of those institutions. This is accomplished by serving as a water resources information outlet through our web site, by serving as a research facilitator through our annual grants competition and by operating as a catalyst for research and educational projects and programs across South Carolina. The Water Center also serves as a conduit for information necessary in the resource management decision-making arena as well as the water policy arena of the state.

While continuing to be involved with numerous water issues across the state including membership on an ad hoc statewide committee identifying policy issues related to primary water concerns and analyzing population growth impacts on water resources, the Water Center is collaborating with multidisciplinary teams investigating natural system/social system interactions. The SCWRC also serves on the Savannah River Basin Advisory Council to assist SCDHEC and the SC Department of Natural Resources with management recommendations as well as serving on SCDNR's advisory group for the state water plan. The SCWRC has recently concluded a cooperative study with the US Army Corps of Engineers and six counties surrounding Lake Hartwell to determine economic impacts of changing lake levels due to drought and other circumstances. Similar projects have been funded by Duke Energy to study Lakes Keowee and Thurmond, also within the Savannah River Basin. The SCWRC is teaming up with American Rivers, the AWWA and the North Carolina Water Resources Research Institute to hold workshops in 2014 to assist municipal water providers with water loss auditing.

The SCWRC has reaffirmed relationships with key individuals from the South Carolina Department of Natural Resources, the South Carolina Department of Health and Environmental Control and South Carolina Sea Grant Consortium in order to advise these state agencies that have critical roles in managing the water resources of the state. As an outcome of those meetings, the SCWRC has continued work as a committee member on the Savannah River Basin Advisory Committee for SCDHEC. In addition, the SCWRC is an advisory member of Clemson University's Intelligent River program, a program funded through the National Science Foundation and Clemson University that is designing real time monitoring for South Carolina's rivers. The SCWRC also sits on the South Carolina Sea Grant Consortium's Program Advisory Board and is actively involved on a project with Sea Grant to investigate alternatives to beach renourishment for communities threatened by sea level rise. Researchers at the SCWRC recently submitted a proposal to SC Seagrant to study the economic and fiscal impacts of shoreline change in several communities across the state.

In its relationship with the South Carolina Department of Natural Resources and the South Carolina Department of Health and Environmental Control, the SCWRC has collaborated on developing a framework for a new water plan for the state of South Carolina. Water supply plans vary in their content depending on need and governmental mandate. There are some basic elements that appear in all regional plans, including an assessment of existing supply, water demand forecasting based on population and economic sector projections with assumptions and scenarios, demand side control measures, and plan implementation, monitoring and evaluation. For the South Carolina water planning effort, SCDHEC and SCDNR will first provide a clear and concise mandate with specific objectives for regional and statewide water plans, facilitate a stakeholder driven process to derive water sustainability objectives, develop and execute a consistent and uniform approach for engaging stakeholders in developing regional water plans, utilize a systemic approach to integrate emerging water monitoring technologies for a cost effective program, carefully evaluate economic development opportunities by region, and foster a public private partnership for process management and funding.

Clemson University and the SCWRC will support SCDHEC and SCDNR in developing local, regional and statewide water plans. Clemson University seeks a role similar to that played by the University of Georgia in

assisting the Georgia Department of Natural Resources in facilitating stakeholder driven regional planning to insure the water-planning mandate is followed and that consistent regional meetings are held that meet specified goals and objectives. Clemson University has the capability and capacity to support SCDHEC and SCDNR through this demanding process. Clemson University has demonstrated statewide leadership in addressing water resource issues through focused research and education programs, statewide Extension Service programs, development of an EPA-Designated Center for Watershed Excellence, and hosting the statewide biennial South Carolina Water Resources Conference to address water issues impacting multiple stakeholders.

Finally, The SCWRC has been an active participant in the South Carolina Water Conference Planning Committee. The previous South Carolina Water Conference was held in October of 2012. The next conference will be held in October of 2014 with the SCWRC being an active co-sponsor while leading and running the Water Policy and Planning track of papers and presentations. The Water Center is a sponsor, evaluates presentations, moderates all water policy tracks, and encourages graduate student presentations and research. This year, the conference will publish the first issue of the South Carolina Water Resources Journal based upon papers from the past conference. The SCWRC has been an active participant in getting the journal started and the director is one of five editors for the journal.

Research Program Introduction

The South Carolina Water Resources Center is part of the only federally mandated research network that focuses on applied water resources research, education, training and outreach. The SCWRC provides a direct and vital link between federal water interests and needs, and the academic expertise located within the South Carolina's research universities. This provides a mechanism for ensuring state, regional, and national coordination of water resources research, the education of future water professionals, and the transfer of results and outcomes to state and federal water professionals. The matching requirements of the program ensures that the state of South Carolina directly invests in water research and training.

Over the past year the SCWRC has become a member of Clemson University's Water-Energy Consortium (WEC). The Water-Energy Consortium is a multidisciplinary group of CU faculty members, designated as WEC Fellows, who have assembled their knowledge and expertise to address an important global challenge: the Water-Energy Nexus. The nexus between water and energy encompasses energy aspects of water systems (energy footprint of water production), and water aspects of energy systems (water footprint of energy production). Besides the direct connection between water and energy, the WEC takes a broader perspective on sustainability, involving reduction of greenhouse gas (GHG) emissions and the environmental impact of both water and energy systems. While low unit costs are important, they are only part of the decision-landscape of sustainable water and energy systems. Added considerations are technology resilience within the context of climate change, and technology adaptation within the context of different climatic (temperate, arid, and tropical) regions.

The vision of the WEC is to promote global recognition of Clemson University as being at the forefront of research addressing the water-energy nexus. The mission of the WEC is to contribute research leading to technology innovations in water systems with a minimization of energy and carbon footprints as well as energy systems with a minimization of water and carbon footprints. Within the framework of the WEC, five strategic research themes have been identified: 1. Innovative, energy-efficient water/wastewater purification processes and systems 2. Improved water efficiency of energy resource development, and production processes and systems 3. Material science in water and energy processes and systems 4. Water and energy informatics, sensors, monitoring, and modeling 5. Water and energy management, policy, and economics

While the SCWRC will be involved to various degrees in all themes of the WEC, but has agreed to be a leader of theme number five. The WEC will seek funding from various agencies and foundations in order to accomplish its mission.

The SCWRC continues to be involved with numerous water issues across the state and region assisting in identifying policy issues related to primary water concerns. As one example, drought conditions across the region over the past decade have left communities concerned about the potential impacts of the scarcity of this key resource. Over the past four years, The SCWRC completed 3 studies along the Savannah River Basin studying the economic impacts of changing lake levels due to drought and other circumstances. These were sponsored by the US Army Corps of Engineers and Duke Energy. This work has led to multidisciplinary discussions with researchers in both South Carolina and Georgia to develop opportunities for more basin wide analysis. Currently the SCWRC is working with researchers from the Southeaster Natural Sciences Academy, Augusta State University in Augusta, Georgia and the U.S. Army Corps of Engineers to adopt some of the economic impact techniques to the lower Savannah River Basin and the Savannah Harbor in Savannah, Georgia. These impact studies could also influence the proposed Jasper Port planned for development on the South Carolina side of the Savannah Harbor area.

These discussions are also fuelled by the concern that without the appropriate research and dialogue between the states, this multi-state resource could become a contentious legal issue as other states have experienced.

The SCWRC in conjunction with faculty from Clemson's Department of Civil Engineering and Department of Mechanical Engineering developed an NSF proposal with statisticians and climatologists from other states to undertake a basin wide study of current and future supply and demand conditions using an experimental design framework estimating multiple climate, population, land use and water policy changes across the basin.

The SCWRC continues to work closely with the Strom Thurmond Institute's Economic Modeling Laboratory. The SCWRC and the Economic Modeling Lab recently submitted proposals to the South Carolina Seagrant Consortium for research focused on valuing the economic costs/benefits of shoreline change and shoreline management structures.in respect to private beach communities. In traditional beach renourishment analyses the gains originate largely from outside tourism but where do the gains originate without this major driver? Private communities are still impacted by chronic erosion, sea level rise, and concerns over sustainable shoreline development and management. Moreover, without public beach access these communities are not candidates for federal subsidies and/or loans targeted towards beach re-nourishment. As a result, research that begins to understand the impact of shoreline change by modeling the value and options of shoreline characteristics and management can advance our knowledge of potential climate change impacts now and in the future.

The funding for USGS 104b projects continues to provide research that is critical to water resources management in South Carolina and beyond. Two SCWRC/USGS funded projects are finishing up in 2014: 1) "Enhancing satellite measurements of water surface temperature using a thermal model of the lake surface for improved evaporation estimates" with John Saylor (Clemson University) as principal investigator and Nigel Kaye (Clemson University) as co-principal investigator; and 2) "Effects of Pharmaceutical Photodegradation Products in Freshwater On Local Amphibians" with Allison Welch (College of Charleston) as principal investigator and Wendy Cory (College of Charleston) as co-principal investigator.

This year the Water Center intends to oversee the funding of two research studies: 1) "Low impact development (LID) stormwater management techniques as a tool for mitigating climate change induced increases in rainfall intensity and frequency" with Nigel Kaye (Clemson University) as principal investigator and William Martin III (Clemson University) as co-principal investigator; and 2) "Monitoring of organic pollutants in the Savannah River, using a buoy-deployed data collection network" with Peter van den Hurk (Clemson University) as principal investigator and Cindy Lee (Clemson University) as co-principal investigator.

Effects of Water Pollution on Fish Health in the Savannah River

Basic Information

Title:	Effects of Water Pollution on Fish Health in the Savannah River
Project Number:	2012SC80B
Start Date:	5/1/2012
End Date:	4/30/2013
Funding Source:	104B
Congressional District:	SC-003
Research Category:	Not Applicable
Focus Category:	Water Quality, Toxic Substances, Surface Water
Descriptors:	
Principal Investigators:	Peter Van Den Hurk, Michael H. Paller

Publications

1. The results will be presented later this year at the annual meeting of the Society for Environmental Toxicology and Chemistry in Nashville, November 17-21, 2013.
2. The results will be presented later this year at the annual meeting of the Society for Environmental Toxicology and Chemistry in Nashville, November 17-21, 2013.

Progress Report, June 18, 2013

"Effects of water pollution on fish health in the Savannah River."

Peter van den Hurk, Clemson University, Michael Paller, Augusta State University

Funded by:

South Carolina Water Research Center

Introduction

In 2009 the Savannah River was ranked in the top ten of America's most contaminated rivers by Environment America, a leading conservation organization. Because of the major economic impact this river has on surrounding counties and states, water quality and ecosystem health are of great concern. The Savannah River provides a large number of services, like providing drinking water, supporting recreational activities (fishing and boating), supply of cooling water and dilution and natural cleansing of liquid wastes from industries and waste water treatment plants. Some major industrial manufacturing plants discharge their wastewater on the river in the Augusta area, in addition to contaminants originating from other point sources like wastewater treatment plants and non-point sources like urban run-off and atmospheric deposition. Also, legacy contaminants discharged by the Department of Energy's Savannah River Site are still of concern in the middle part of the river.

Over the last decade, several studies have investigated the concentrations of heavy metals like mercury and selenium in the Savannah River ecosystem. These studies have led to fish consumption advisories, especially because of elevated mercury levels in fish fillets. However, very little is known about the concentrations and effects of organic pollutants in the Savannah River. Given the knowledge about the sources, these pollutants may contribute significantly to poor fish health in the river. We proposed to sample largemouth bass (*Micropterus salmoides*) and sunfish species (*Lepomis sp.)* to investigate the effects of pollutants on the health of these top predator species. Fish health will be assessed through measuring a suite of health parameters that include somatic indices, blood and bile analysis and expression of detoxifying enzymes and proteins in liver.

The main objective of this study is to obtain a current overview of the exposure to, and health effects of environmental pollutants on fish species in the Middle Savannah River. This will provide critical information to environmental managers and conservation organizations, and creates a venue to educate local interest groups about the health of the river. In addition, the project has created opportunities to involve undergraduate and graduate students in applied environmental research, and created new research collaborations between environmental investigators from Augusta State University, USC Aiken, the Savannah River National Laboratory and Clemson University.

Field collections and biomarker assays

Fish were collected from 14 sites along the Savannah River, ranging from just below the Strom Thurmond Reservoir, down to the Johnson Landing boat ramp, due west of Allandale, SC. We collected around 185 fish in total, most of them were sunfish species in addition to 32 largemouth bass. Of all the fish we collected a blood sample, and liver and gall bladder samples were preserved. Bile was collected from the gall bladders, and was analyzed for fluorescence as a measurement for metabolites of polynuclear aromatic hydrocarbons (PAHs). To normalize these data the total protein content was also measured in the bile samples. We are in the process now of analyzing the bile samples for estrogenic compounds, using an estrogen receptor binding assay after deconjugating these compounds through an enzymatic reaction, followed by extraction. The liver samples will be homogenized and analyzed for cytochrome P450-1A activity, using the EROD assay. In addition glutathione-S-transferase (GST) activity was measured in the liver homogenates as a general indication for oxidative stress. Samples will also be analyzed using the TBAR assay, which is indicator for cell membrane damage as a result of oxidative stress. Blood samples will be analyzed for inhibition of acetylcholinesterase as a marker for pesticide exposure, and plasma samples of male fish will be screened for expression of vitellogenin, a female yolk protein that is induced in male fish by exposure to environmental estrogens.

Preliminary Results

The results of the bile fluorescence show that in in the city of Augusta, and downstream of the outfall of the paper mill significantly higher concentrations of PAHs are found. The higher concentrations in Augusta are clearly related to higher urbanization in this area, and may be related to road run-off. Recent findings have demonstrated that especially run-off from parking lots and driveways that have been treated with seal coats contribute large amounts of PAHs to receiving urban creeks. The outfall of the paper mill has likely higher PAH concentrations as a result of the breakdown of natural organic material is paper pulp. Despite the retention of paper mill effluent in large basins before discharge into the river this is not sufficient to break down these PAHs.

Products

The results will be presented later this year at the annual meeting of the Society for Environmental Toxicology and Chemistry in Nashville, November 17-21, 2013.

Personnel involved

In addition to the principal investigators (Paller and Van den Hurk), two graduate students in the Environmental Toxicology at Clemson University are involved in the project: Phenny Mwanga was part of the sampling crew and David Wyker will be involved in sample analysis. Furthermore assistance in the field and the lab was provided by faculty from the University of South Carolina Aiken: Virginia Shervette generously donated time and equipment to assist in the sampling program, and Michelle Harmon provided access to lab equipment to prepare blood samples for further analysis.

A Modeling Study of Water Shortages in the Savannah River Basin: Sensitivity of Water Availability to Evaporative Loss and Climate Change

Basic Information

Title:	A Modeling Study of Water Shortages in the Savannah River Basin: Sensitivity of Water Availability to Evaporative Loss and Climate Change
Project Number:	2012SC81B
Start Date:	5/1/2012
End Date:	4/30/2013
Funding Source:	104B
Congressional District:	SC-003
Research Category:	Not Applicable
Focus Category:	Management and Planning, Drought, Models
Descriptors:	
Principal Investigators:	Nigel Kaye, John R Saylor

Publications

1. Phillips, R., Saylor, J. R., & Kaye, N.B. Inclusion of evaporation physics in modeling of water availability in the Savannah River Basin" South Carolina Water Resources Center 2012 Conference (2012) (Poster - 2nd Place)
2. Phillips, R., Saylor, J. R., & Kaye, N.B. The eff ect of uncertainty in evaporation rates on water availability in the Savannah River Basin" (In preparation)
3. Phillips, R., Saylor, J. R., Kaye, N.B., & Gibert, J. A comparison of remote sensing estimates of lake evaporation with pan evaporation measurements along the Savannah River Basin" (In preparation)
4. White, M., Phillips, R., Saylor, J. R., & Kaye, N.B., A statistical analysis of daily and monthly evaporation rates from the Savannah River Basin using surface temperature obtained from the MODIS sensor" (In preparation)
5. Phillips, R., Saylor, J. R., & Kaye, N.B. Inclusion of evaporation physics in modeling of water availability in the Savannah River Basin" South Carolina Water Resources Center 2012 Conference (2012) (Poster - 2nd Place)
6. Phillips, R., Saylor, J. R., & Kaye, N.B. The eff ect of uncertainty in evaporation rates on water availability in the Savannah River Basin" (In preparation)
7. Phillips, R., Saylor, J. R., Kaye, N.B., & Gibert, J. A comparison of remote sensing estimates of lake evaporation with pan evaporation measurements along the Savannah River Basin" (In preparation)
8. White, M., Phillips, R., Saylor, J. R., & Kaye, N.B., A statistical analysis of daily and monthly evaporation rates from the Savannah River Basin using surface temperature obtained from the MODIS sensor" (In preparation)

Savannah River Basin Evaporation Research

June 21, 2013

RE: SCWRC/NIWR Annual Reports

Dear Lori,

Since the start of this project our goal has been to determine what specific conditions will cause a failure in water availability prediction methods due to uncertainties in evaporation prediction, future water use due to population and industry growth, and changing climatic conditions within the Savannah River Basin. We have been working vigorously in researching this topic and are winding down as we complete the last segments of the project. Provided below is a brief summary/update of the work we have completed to date, future work to be completed, and publications resulting from the research.

Upon beginning the project, much of our work was focused on current data and approaches of estimating evaporation with much higher accuracy than previous researchers. In order to reduce the uncertainties in evaporation prediction, we decided the best approach would be to estimate reservoir evaporation from each of the Savannah lakes using multiple mass transfer based evaporation parameterizations with remotely sensed satellite data, in particular surface temperature measurements. Remotely sensed surface temperature data is readily available and can be obtained directly or indirectly from many satellite platforms. Our research has focused on remotely sensed surface temperature obtained from the MODIS sensor on board NASA's Terra and Aqua satellites.

Using MODIS derived surface temperature data and upper air meteorological measurements obtained via airport weather stations, estimates of evaporation from each lake at four times throughout the day from July 2002 to present have been generated. Typically evaporation estimates are calculated using daily averages and are calculated once per day; however, we believe estimating evaporation at multiple points throughout the day will help capture the diurnal cycle of evaporation and reduce the uncertainty in the prediction of lake evaporation. The current evaporation estimates used by the USACE when performing reservoir models and developing water availability plans are obtained via pan evaporation observations. Therefore, we have decided to include pan based lake evaporation estimates as a baseline comparison with the mass transfer, satellite based evaporation estimates. After examining the data, it was difficult to characterize the underlying trends and differences between the estimates. As a result, long-term evaporation trends for each lake and evaporation model have been generated. Analysis of these results has yielded not only differences among the underlying trends between models, but differences in the trends from lake to lake.

Differences among long-term evaporation trends have lead us to believe that the current USACE water availability model may be sensitive to evaporation. In order to determine the uncertainties in water availability prediction, we have decided to perform a sensitivity analysis of the current water availability model used by USACE with respect to evaporation predictions. In order to perform this step the current water availability model was obtained from USACE. This model was developed within a program named HEC-REsSim and incorporates the current drought contingency/water management plan, along with reservoir and power plant operational data. Using this model and the aforementioned evaporation estimates, we have been able to simulate

historical reservoir elevations for each of the Savannah lakes and record yearly minimum lake elevations resulting from each evaporation parameterization. Upon preliminary examination of the results, we have found that under normal climate conditions (i.e. non-drought periods) reservoir elevations are relatively insensitive to evaporation predictions; however, under drought conditions, the predicted reservoir elevations are quite sensitive to evaporation predictions. So far, we have seen differences in predicted elevations on the order of ± 5-10 feet. Analysis of these results are still underway and continue to be a major component of the research.

After evaluating the effect of evaporation predictions on current water availability predictive tools, our next effort has been to understand the effects of population and industry growth along the basin coupled with evaporation. Since water consumption and evaporative loss represent the major loss of water within the basin, we believe future water use will have a negative effect on the predictive capabilities of the HEC-ResSim model. In researching this component of the project, future water withdrawal rates have been analyzed and obtained for each major diversion located within the Savannah River Basin and have been incorporated within the current HEC-ResSim model (i.e. current hydrology setting), as well as the aforementioned evaporation estimates. This step has produced simulated reservoir elevations as a function of evaporation predictions and future water use. The results are similar to the previous reservoir elevations; however, the effect of future water use seems to increase the variability in reservoir predictions under drought conditions. In evaluating these effects on the current water availability model, we are continuing our analysis and hope to provide concrete results upon project completion.

The last component of the project is to couple the effects of changing climate conditions with evaporation predictions and future water use within the current water availability model. In order to complete this aspect, we have been researching and analyzing current approaches of obtaining down-scaled climate change data for the Savannah River Basin. There are several pros and cons associated with each approach and this will play a role in the final method chosen for the project. Once we obtain the climate change data for the basin, we will incorporate the data within HEC-ResSim, along with evaporation estimates and future water use, and simulate reservoir elevations as discussed earlier. With the simulated reservoir elevations we hope to understand the effect of changing climate conditions on the uncertainty of the current water availability model.

Publications

1. Phillips, R., Saylor, J. R., & Kaye, N.B. "*Inclusion of evaporation physics in modeling of water availability in the Savannah River Basin*" South Carolina Water Resources Center 2012 Conference (2012) (Poster - 2nd Place)
2. Phillips, R., Saylor, J. R., & Kaye, N.B. "*The effect of uncertainty in evaporation rates on water availability in the Savannah River Basin*" (In preparation)
3. Phillips, R., Saylor, J. R., Kaye, N.B., & Gibert, J. "*A comparison of remote sensing estimates of lake evaporation with pan evaporation measurements along the Savannah River Basin*" (In preparation)
4. White, M., Phillips, R., Saylor, J. R., & Kaye, N.B., "*A statistical analysis of daily and monthly evaporation rates from the Savannah River Basin using surface temperature obtained from the MODIS sensor*" (In preparation)

Sincerely,

Ryne C. Phillips, John R. Saylor, & Nigel B. Kaye

Enhancing Sattelite Measurements of Water Surface Temperature Using a Thermal Model of the Lake Surface for Improved Evaporation Estimates

Basic Information

Title:	Enhancing Sattelite Measurements of Water Surface Temperature Using a Thermal Model of the Lake Surface for Improved Evaporation Estimates
Project Number:	2013SC90B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	SC-003
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Quantity, Surface Water, Models
Descriptors:	None
Principal Investigators:	John R Saylor, Nigel Kaye

Publications

There are no publications.

Progress Report for the South Carolina Water Resources Center

"Enhancing satellite measurements of water surface temperature using a thermal model of the lake surface for improved evaporation estimates"

John Saylor (Clemson University) principal investigator
Nigel Kaye (Clemson University) co-principal investigator

Inland lakes and reservoirs are used throughout the world for irrigation, power generation, and drinking water. Evaporation is one of the primary losses of water in inland lakes and reservoirs, and measuring and predicting this evaporative loss is important in water resources management. However, quantitatively measuring evaporation rates on large bodies of water is difficult. Direct measurements from evaporation pans suffer from errors due to the fact that the meteorological conditions on shore differ significantly from those on the adjacent lake. Parameterizations for evaporation from a water surface exist and potentially represent a significant improvement over shore-based pan measurements, but these require accurate measurements of the water surface temperature. Our earlier SCWRC work (Kaye and Saylor) demonstrated how extant satellites (primarily Aqua and Terra) can provide lake surface temperature. However these satellites provide a maximum of four overpasses per day and hence only four surface temperature measurements and therefore only four evaporation estimates per day. Estimates of evaporation rates from reservoirs can be significantly improved by developing a model of the diurnal variation in lake surface temperature which, combined with four satellite measurements could provide 24 hours worth of water surface temperature and concomitant improvement in estimated evaporation rates from lakes and reservoirs. Obtaining a functional description of the diurnal variation of lake surface temperature was the goal of this current SCWRC project (Saylor and Kaye).

There are many models in the literature which can be used to calculate the surface temperature and mixed layer depth of a lake. However, most of these models deal with seasonal variation, rather than diurnal. Predicting diurnal variation is especially difficult because the surface temperature is affected by mixing of quiescent waters by buoyancy and wind forcing. The mixing of the surface layer (or mixed layer depth) is not well understood on a diurnal basis, and hence had to be better understood to obtain a diurnal model of surface temperature. The mixed layer model used in this work was originally derived by Kraus and Turner to describe mixing in the upper layers of the ocean. Fischer etal. modified this model to describe mixing in inland lakes and reservoirs. The overall model approach is to use an energy balance at the surface of the lake, conservation of energy of the mixed layer, and a turbulent kinetic energy balance to solve the non-linear equations for surface temperature and mixed layer depth.

The model simulation has been performed on Lake Hartwell using ambient weather conditions at the Anderson weather station. The current methodology is to scale the simulation results by the daily minimum and maximum temperature, and the daily

sunrise and sunset times. We have used the averaged simulation results and obtained a diurnal function which is essentially a Fourier series comprised of the daily frequency and its three subsequent harmonics, with four pre-factors that are determined from the satellite measurements. We are in the process of determining the rms error of the function compared to the satellite overpass and the simulation results. Though funding has ended, the PI's are using in-house funding to continue the work.

Effects of Pharmaceutical Photodegradation Products in Freshwater on Local Amphibians

Basic Information

Title:	Effects of Pharmaceutical Photodegradation Products in Freshwater on Local Amphibians
Project Number:	2013SC91B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	SC-001
Research Category:	Biological Sciences
Focus Category:	Non Point Pollution, Ecology, Water Quality
Descriptors:	None
Principal Investigators:	Allison Welch, Wendy Cory

Publications

There are no publications.

Project report, 5/30/2014

Effects of pharmaceutical photodegradation products in freshwater on local amphibians

Allison M. Welch[1] and Wendy C. Cory[2]
[1] Department of Biology and [2] Department of Chemistry and Biochemistry, College of Charleston, SC

Project overview – This project aims to test the biological effects of two popular over-the-counter nonsteroidal anti-inflammatory drugs, naproxen and ibuprofen, and their photodegradants on local amphibians. These pharmaceuticals are not completely removed during wastewater treatment leading to their release into the environment, where they photodegrade. The photodegradants have chemical properties that predict greater toxic than the parent compounds. To date, we have tested acute and chronic toxicity of naproxen and its two degradants as well as acute toxicity of ibuprofen and its degradant, using tadpoles of the southern toad, *Anaxyrus terrestris*. Current work focuses on replicating these results and extending the work to include assessing relevant mixtures of parent compound and degradants as well as testing chronic effects of ibuprofen and its degradant.

Research results to date – Results to date indicate that the median lethal concentration (LC50) at 96 hours is higher for naproxen than for either of its degradants, and higher for ibuprofen than for its degradant. Thus, as predicted, the photodegradants are more toxic to amphibian larvae than are the parent compounds. All LC50s measured to date have been >1ppm, indicating slight to moderate toxicity. Similarly in a chronic test in which tadpoles were exposed until metamorphosis, naproxen was less toxic than its two degradants. Lowest observed effect concentrations (LOEC) in the chronic toxicity test for naproxen and its photodegradants were also >1 ppm. In addition, an experiment comparing acute toxicity of ibuprofen and its degradant individually and in combination revealed a moderate synergism between these two compounds, as the combination was more toxic than predicted based on the effects of each compound acting in isolation.

Dissemination – Results of this research have been presented at two national or international conferences: Society for Integrative and Comparative Biology in Austin, TX and Society for Toxicology and Environmental Chemistry in Basel, Switzerland, as well as one regional meeting, the Southeastern Regional Meeting of the American Chemical Society in Atlanta, GA. In addition, a manuscript is in preparation that will include some of the current results.

Education and training outcomes – Four undergraduate students have been trained on this project, leading to one Bachelor's Essay and three independent studies to date. These students have given four presentations at off-campus venues (Colonial Academic Alliance, Society for Integrative and Comparative Biology, Southeast Regional Meeting of the American Chemical Society) as well as several presentations at the College of Charleston.

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	3	0	0	0	3
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements

Completed work as Past President of NIWR Board of Directors in October.

Successfully conducted SCWRC statewide research solicitation under the guidelines of USGS.

Served on Planning Committee of the S.C. Water Resources Conference.

Served on editorial committee for the Journal of South Carolina Water Resources

Co-sponsored second workshop with SC Rural Water Association, American Rivers and SCDHEC on water auditing for municipal water systems.

Initiated work with partners to do remote sensing research for habitat preservation in Brazil.

Lakelands Regional Workforce Alliance Mapping Research Project Overview Produced workforce mapping efforts and conducted a preliminary demographic analysis for the Alliance.

Worked with Clemson University Environmental Engineering and Earth Sciences to co-host global climate change lectures.

Worked with Clemson University Political Science to co-host their Globalization Lecture Series.

Worked with Library and campus historians to host T. Boone Pickens as a speaker for Calhoun Lecture Series.

Initiated work to build a partnership for a public/private national technology research center to be housed at Clemson University.

Served on the Savannah River Basin Advisory Council.

Served on the Carolinas Integrated Sciences & Assessments Advisory Board

Served on the SC Sea Grant Consortium Coastal Communities Advisory Board

Served on SCDNR State Water Plan Advisory Committee

Served on the SC Sea Grant Consortium Program Advisory Board

Nominated to serve on the Universities Council on Water Resources National Board