Alabama Water Resources Research Institute
Annual Technical Report
FY 2014

Introduction

The Alabama Water Resources Research Institute (AL-WRRI) was created in 1964 by the Alabama Legislature. In 2007 the AL-WRRI was combined with the newly created Auburn University Water Resources Center (AU-WRC), and in 2008 it was designated as part of the Auburn University Center of Excellence for Watershed Management by EPA.

The AU-WRC and AL-WRRI function as a single university-based interdisciplinary, problem-oriented research and technology center under one Director with primary support from Auburn University, and additional financial support from the federal government through the USGS, and numerous other contracts and grants that enables the programs to address broad national needs and relevant industrial technology. The Alabama Water Resources Center and Research Institute coordinates research programs that contribute to the solutions of present and emerging water resources problems. In carrying out this mission, the Institute has developed a broadly based research, training, information transfer, and public service program involving personnel from many academic disciplines in the state's research universities

The Alabama Water Resources Center and Research Institute is one of 54 water resources institutes nationwide authorized by the federal Water Resources Research Act. The state-based Water Resources Research Institutes are located at land grant universities and function as a nation-wide network to promote research and information dissemination on the state's and nation's water resources problems.

Research Program Introduction

The essential ingredient for determining proper policies and practices is factual information. Often such information must be obtained by means of scientific research. The Institute conducts a program that stimulates, sponsors, and provides for research, investigation, and experimentation in the fields of water and of resources as they affect water, and encourages the training of scientists in the fields related to water.

Objectives of the AU-WRC and AL-WRRI are:

To plan, conduct and otherwise arrange for competent research that fosters (a) the entry of new research scientists into the water resources fields, (b) the training and education of future water scientists, engineers and technicians, (c) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena, and (d) the dissemination of research results to water managers and the public.

To identify major research needs and develop for Alabama and the Southeastern Region short- and long-term research priorities. To encourage research applying to other environmental resources closely associated with water.

To maintain close consultation and collaboration with governmental agencies, public groups, and cooperate closely with other colleges and universities in the state that have demonstrated capabilities for research, information dissemination, and graduate training in order to develop a statewide program designed to resolve state and regional water and related land problems.

Forecasting toxic cyanobacterial blooms throughout the southeastern U.S.

Basic Information

Title:	Forecasting toxic cyanobacterial blooms throughout the southeastern U.S.
Project Number:	2011AL121G
USGS Grant Number:	G11AP20212
Start Date:	9/1/2011
End Date:	8/31/2014
Funding Source:	104G
Congressional District:	3rd
Research Category:	Water Quality
Focus Category:	Models, Nutrients, Surface Water
Descriptors:	None
Principal Investigators:	Alan Elliott Wilson, Kevin Schrader, Russell Alan Wright

Publications

1. Wilson, Alan E.; Michael F. Chislock. In press. Ecological control of cyanobacterial blooms in freshwater ecosystems. in ed. Aloysio Ferrão-Filho,Cyanobacteria: Toxicity, ecology, and management. Hauppauge, New York, Nova Science Publishers, xx-xx.
2. Wilson, Alan E.; Michael F. Chislock. In press. Ecological control of cyanobacterial blooms in freshwater ecosystems. in ed. Aloysio Ferrão-Filho,Cyanobacteria: Toxicity, ecology, and management. Hauppauge, New York, Nova Science Publishers, xx-xx.
3. Wilson, Alan E.; Michael F. Chislock. In press. Ecological control of cyanobacterial blooms in freshwater ecosystems. in ed. Aloysio Ferrão-Filho,Cyanobacteria: Toxicity, ecology, and management. Hauppauge, New York, Nova Science Publishers, xx-xx.
4. Doster, Enrique; Chislock, Michael F.; Roberts, John; Kottwitz, Jack; and Wilson, Alan E. 2014. Recognition of an important water quality issue at zoos: prevalence and potential threat of toxic cyanobacteria. Journal of Zoo and Wildlife Medicine 45(1):174 177.
5. Kasinak, Jo Marie, 2013, Methods for monitoring and controlling freshwater harmful algal blooms, MS thesis, Department of Biological Sciences, Auburn University, Auburn, Alabama, 64 pages. Olsen, Brianna; Chris Smith; Michael Chislock; Jo Marie Kasinak; and Enrique Doster. 2013. Letter to the Editor: Association for the Sciences of Limnology and Oceanography (ASLO) 2013 Annual Meeting: Students' perspectives. ASLO Bulletin 22(3):83 84. Wilson, Alan; Michael Chislock, Enrique Doster; Russell Wright, Jack Kottwitz, Heather Walz, and Heidi Rose. 2013. Toxic algae threaten livestock health. The Alabama Cattleman June 2013:16 17.
6. Wilson, Alan E.; Michael F. Chislock. In press. Ecological control of cyanobacterial blooms in freshwater ecosystems. in ed. Aloysio Ferrão-Filho,Cyanobacteria: Toxicity, ecology, and management. Hauppauge, New York, Nova Science Publishers, xx-xx.
7. Doster, Enrique; Chislock, Michael F.; Roberts, John; Kottwitz, Jack; and Wilson, Alan E. 2014. Recognition of an important water quality issue at zoos: prevalence and potential threat of toxic cyanobacteria. Journal of Zoo and Wildlife Medicine 45(1):174 177.
8. Kasinak, Jo Marie, 2013, Methods for monitoring and controlling freshwater harmful algal blooms, MS thesis, Department of Biological Sciences, Auburn University, Auburn, Alabama, 64 pages. Olsen, Brianna; Chris Smith; Michael Chislock; Jo Marie Kasinak; and Enrique Doster. 2013. Letter to the Editor: Association for the Sciences of Limnology and Oceanography (ASLO) 2013 Annual

Meeting: Students' perspectives. ASLO Bulletin 22(3):83 84. Wilson, Alan; Michael Chislock, Enrique Doster; Russell Wright, Jack Kottwitz, Heather Walz, and Heidi Rose. 2013. Toxic algae threaten livestock health. The Alabama Cattleman June 2013:16 17.

ANNUAL TECHNICAL REPORT SYNOPSIS

A. PROJECT TITLE:
   USGS Project 2011AL121G – Forecasting toxic cyanobacterial blooms throughout the southeastern U.S.
   Project website - http://wilsonlab.com/bloom_network/
B. PRIMARY PI(s): Name(s), Title(s) & Academic Rank(s)
   Alan E. Wilson, Assistant Professor, Ph.D.
C. OTHER PI(s): Name(s), Title(s) & Academic Rank(s)
   Russell A. Wright, Associate Professor, Ph.D.
   Kevin Schrader, Microbiologist, Ph.D.
D. START DATE:
   1 October 2011
E. END DATE:
   30 September 2014
F. PROJECT OVERVIEW/SUMMARY: Provide a brief narrative overview or summary of the project.
   Using a novel collaborative approach, we are collecting water quality samples and associated data from 400+ diverse freshwater systems, including lakes, reservoirs, ponds, and rivers, throughout much of the eastern U.S. These samples will be analyzed by the PIs for phycocyanin (cyanobacteria), cyanobacterial toxins, off-flavors, and phytoplankton enumeration. Data generated from these efforts will be used to refine and build models aimed at forecasting blooms of freshwater cyanobacterial blooms. Although the focus of the current project is on the Southeast, we have quickly expanded our efforts beyond this region. We hope to continue this expansion throughout the 3-year project.
G. PROJECT OBJECTIVE(s): Briefly explain the project objectives.
   To enhance our network of water quality managers and scientists throughout the southeastern U.S. aimed at monitoring sites for toxic cyanobacterial blooms.
   To test and refine current models that forecast toxic cyanobacterial blooms and off-flavor events in freshwater lakes, reservoirs, rivers, and ponds throughout the Southeast.
   To train state and federal scientists, water quality managers, and aquaculturists on standard techniques to measure cyanobacterial toxin and phycocyanin concentrations and to identify and enumerate phytoplankton.
   To train graduate and undergraduate students on field sampling and laboratory-based water quality analytical analyses.
   To enhance our existing, user-friendly, interactive website where water quality managers and aquaculturists can determine the risk of their waterbodies for toxic cyanobacterial blooms and/or off-flavor events.
   To create a model collaborative network that can be extended to other U.S. regions.

H. METHODOLOGIES: Briefly explain the research methodology used.

Sample sharing is central to the success of our project. We are also planning to share data among collaborators, but we are most excited about our approach for bringing together scientists in academia, agencies, and industry who all share a common concern – algal blooms. We are leveraging resources provided by our many colleagues throughout the eastern U.S. to collect and analyze water quality samples for us. In turn, we will analyze these samples for phytoplankton, cyanobacteria, and cyanobacterial toxins and off-flavors in order to build algal bloom forecasting models.

I. PRINCIPAL FINDINGS/RESULTS: Explain the results of findings of this research project.

Despite being in our first project year, we have observed a huge interest in our project by agency and academic scientists throughout the eastern U.S. We proposed to get samples and data from 200 sites per year. We will double that estimate in our first year! All of our sampling gear has been shipped to our colleagues (60+ individuals in 13 states and Puerto Rico). Our colleagues will return their samples to us this fall when we will begin our own analyses. We have held two water quality workshops this spring (Orlando and Auburn). Both were well attended (16-17 students each), and we received feedback showing that our students learned a lot about the project and our analytical and modelling approaches. We will be organizing similar workshops next spring. We have also given several presentations at regional and national conferences showcasing this project, and all have generated more excitement about our project and our analytical techniques (especially the phycocyanin analysis). One of Wilson's students is in the process of running a laboratory experiment further validating the utility of our phycocyanin analyses, which we expect to submit for publication later this year. Given the feedback we have received from others, we expect these data to be of broad interest to scientists interested in quickly quantifying cyanobacterial abundance.

J. NOTABLE AWARDS AND ACHIEVEMENTS. List any awards or recognitions for this research

None

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	0
Book Chapters	1
Theses and Dissertations	0
Water Resources Institute Reports	0
Articles in Conference Proceedings	0
Other Publications	0

PROVIDE A CITATION FOR EACH PUBLICATION USING THE FOLLOWING FORMATS:

1. Articles in Refereed Scientific Journals Citation

Author (first author; last name, first name; all others; fist name, last name), Year, Title, Name of Journal, Volume(Number), Page Numbers.

None

2. Book Chapter Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title of chapter, "in" Name(s) of Editor "ed.", Title of Book, City, State, Publisher, Page Numbers.

Wilson, Alan E.; Michael F. Chislock. *In press*. Ecological control of cyanobacterial blooms in freshwater ecosystems. in ed. Aloysio Ferrão-Filho , *Cyanobacteria: Toxicity, ecology, and management*. Hauppauge, New York, Nova Science Publishers, xx-xx.

3. Dissertations Citation

Author (last name, first name), Year, Title, "MS (Ph.D.) Dissertation," Department, College, University, City, State, Number of Pages.

None

4. Water Resources Research Institute Reports Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title, Name of WRRI, University, City, State, Number of Pages.

None

5. Conference Proceedings Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title of Presentation, "in" Title of Proceedings, Publisher, City, State, Page Numbers.

None

6. Other Publications Citation

Author (first author; last name, first name; all others: first name, last name), Year, Title, other information sufficient to locate publications, Page Numbers (if in publication) or Number of Pages (if monograph).

None

L. PRESENTATIONS MADE:

Presenter(s) (last name, first name; all others presentation authors: first name, last name), Year, Title, other information sufficient to identify the venue in which the presentation was made.

Wilson, Alan E.; Russell A. Wright; Kevin. K. Schrader; Gina L. Curvin; Barry H. Rosen; Jennifer L. Graham, 2012, Creating cost-effective regional algal bloom monitoring networks: Extending beyond Alabama. Alabama Water Resources Conference, Orange Beach, Alabama.

Wilson, Alan E.; Russell A. Wright; Kevin. K. Schrader; Gina L. Curvin; Barry H. Rosen; Jennifer L. Graham, 2012, Creating cost-effective regional algal bloom monitoring networks: The Southeast as a case study. 21st SE NALMS Southeastern Lake and Watershed Management Conference. Columbus, Georgia.

Wilson, Alan E.; RajReni B. Kaul; Michael F. Chislock; Gina L. Curvin, 2012, Towards an improved understanding of the factors mediating toxic cyanobacterial blooms throughout the Southeast. Association of Southeastern Biologists, Athens, Georgia.

Wilson, Alan E.; Russell A. Wright; Kevin. K. Schrader; Gina L. Curvin; Barry H. Rosen; Jennifer L. Graham, 2012, Creating cost-effective regional algal bloom monitoring networks. 8th National Monitoring Conference. Portland, Oregon.

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	4
Masters	1
Ph.D.	0
Post Doc	0

Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	0
Ph.D. Dissertations	0

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
X	Biological Sciences
	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
	Social Sciences
X	Water Quality
X	Other: Modelling

O. FOCUS CATEGORIES (mark all that apply with “X” in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
X	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
X	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
	LAW, INSTITUTIONS, & POLICY	LIP
X	MANAGEMENT & PLANNING	M&P
X	METHODS	MET
X	MODELS	MOD
X	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
X	NUTRIENTS	NU
	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
X	SURFACE WATER	SW
X	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
X	WATER QUALITY	WQL
X	WATER QUANTITY	WQN
	WATER SUPPLY	WS

	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: (Enter keywords of your choice, descriptive of the work)
Algal blooms, cyanobacteria, off-flavor, toxin, microcystin, BMAA, cylindrospermopsin, saxitoxin, phytoplankton, modeling, forecasting, monitoring, network, collaboration

Examination of bacterial levels in water and sediment for the development of refined monitoring protocols for inland recreational waters

Basic Information

Title:	Examination of bacterial levels in water and sediment for the development of refined monitoring protocols for inland recreational waters
Project Number:	2014AL165B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	3
Research Category:	Water Quality
Focus Category:	Water Quality, Recreation, Methods
Descriptors:	None
Principal Investigators:	Luxin Wang, Eric Reutebuch

Publication

1. Wang, Luxin and Eric Reutebuch; 2015; Examination of bacterial levels in water and sediment for the development of refined monitoring protocols for inland recreational waters (Final Report), at http://www.aaes.auburn.edu/water/projects/alwrri.php; 29 pp.

Project Report
for
Water Resources Research Institute Program
under
Section 104, Water Resources Act of 1984
to the
Alabama Water Resources Research Institute

In support of the
Research Proposal

Examination of bacterial levels in water and sediment for the development of refined monitoring protocols for inland recreational waters

by

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April, 2015

Examination of bacterial levels in water and sediment for the development of refined monitoring protocols for inland recreational waters

Focus Category
REC; MET; WQL; NPP

Keywords
Public Swimming Waters; Water Quality Monitoring; Swim Beach Monitoring; Bacteria; *E. coli*; *Salmonella*, Pathogens

Duration
March 1, 2014- March 1, 2015

Acknowledgements
The PI and Co-PI would like to acknowledge the many individuals that assisted them in conducting this study. Special thanks to:

- Wind Creek State Park staff and Mr. Bruce Adams for facilitating sampling at Wind Creek State Park,
- Mr. Kevin Casey for facilitating sampling at Camp Cosby,
- Lake Watch of Lake Martin volunteer monitors, Ann Campbell, Dick Bronson, and Judy Palfrey, for assisting in field sampling at Lake Martin,
- Logan Martin Lake Protection Association volunteer monitors, Wayne Wilcox and Margaret Mize, for assisting in field sampling at Lake Logan Martin.

Without their assistance, this study would not have been possible – thanks to them for providing their time and talent to making this study a success.

Identification and Statement of the Major Regional Water Problem
The health and well-being of Alabama's citizens relative to recreational water usage depends on credible and timely monitoring of public swimming areas and other recreational waters to assess these areas for contamination with pathogens and other pollutants. *Escherichia coli* bacteria are commonly used as indicator organisms for the presence of fecal contamination and its associated pathogens in inland waters, while *Enterococci* are used in marine waters (USEPA, 2012). The State (Alabama Department of Environmental Management) routinely monitors swim areas along Alabama's coast (the Coastal Alabama Beach Monitoring Program involves the routine collection of water samples from 25 high use and/or potentially high risk public recreational sites from Perdido Bay to Dauphin Island, for details see http://adem.alabama.gov/programs/coastal). Inland swimming and recreational-use areas are not routinely monitored by the State. With increasing pressures on these inland waters from urban development, industrial needs, agricultural needs and others, there is increasing risk to the public health from contaminated waters (Natural Resources Defense Council, 2013).

The Alabama Water Watch Program (AWW), based at Auburn University, has been training and certifying volunteer citizen monitors in Bacteriological Monitoring since 1996, and attained EPA approval on its bacteriological monitoring protocols in 1999. AWW monitors have been monitoring waters for *E. coli* contamination using AWW's Coliscan Easygel method, and have compiled over 14,300 data records from over 2,000 sample sites throughout the state. Recent citizen monitoring efforts at public swimming areas have suggested significant differences in

E. coli concentrations measured at the same site at different times of the day. Side-by-side monitoring by citizen monitors, agency personnel and private laboratory personnel have also yielded differences. Recent research supports these citizen monitoring results. Research results and citizen data throw into question the adequacy of monitoring public swim areas only once a day. And if sampled once a day, what time of day would be most protective of public health. They also throw into question the source or sources of *E. coli* – emanating from the gut of warm-blooded animals, or also emanating from sources living out in the environment, such as in beach/lake/stream sediments.

Related Research

Recent research supports observed AWW citizen monitoring results indicating significant diurnal differences in bacterial contamination at public swimming areas that appear to be emanating from bacterial reservoirs harbored in sand/sediments underlying these areas.

Jamieson et al. (2005) found that the association of microorganisms with sediment particles is one of the primary complicating factors in assessing microbial fate in aquatic systems. They employed an experimental procedure, involving the use of a tracer-bacteria, to simulate the transport and deposition of bacteria-laden bed sediments in a small alluvial stream during steady flow conditions. The experimental data and a mathematical model were used to determine dispersion coefficients, deposition rates, and partitioning coefficients for sediment-associated bacteria in two natural streams.

Garzio-Hadzick, et al. (2010) found that in agricultural watersheds that were studied, substantial numbers of *E. coli* may reach surface waters, and subsequently be deposited into sediments, along with fecal material in runoff from land-applied manures, grazing lands, and/or wildlife excreta; and *E. coli* survived in sediments much longer than in the overlaying water.

Piorkowski et al. (2013) found that *E. coli* concentrations in streambed sediments were significantly different among monitoring sites during baseflow; significant interactive effects occurred among monitoring sites and morphological features following stormflow; and *E. coli* can persist in streambed sediments and influence water quality monitoring programs through their resuspension into overlying waters.

Ikonen et al. (2013) found significant differences in *E. coli* concentrations measured at the same site at different times of the day; and that *E. coli* levels in the water directly correlated with activity in the water, UV absorbance and turbidity.

Statement of the Results, Benefits, and Information

Expected project results include the following:

- Evaluation and quantitative estimates of bacterial contamination (*E. coli, Salmonella*) at swimming/public use areas at various times of the day throughout the recreational season (April-September) at two major reservoirs in Alabama, lakes Martin and Logan Martin.

- Evaluation and quantitative estimates of bacterial contamination (*E. coli, Salmonella*) in the sediment of these swimming/public use areas at various times of the day throughout the recreational season.

- Evaluation of coincident water column sampling by AWW volunteer monitors and state agency personnel.

- Examination of relationships among project parameters including water column bacterial concentrations, sediment bacterial concentrations, time of day and human activity levels.

Expected project benefits and information include the following:

- Development of recommendations for swim beach/recreation area monitoring protocols that are most protective of human health will be developed.

- Dissemination of project results, conclusions and recommendations to AWW volunteer monitors throughout the state and to state agencies involved in monitoring public waters.

- Improved monitoring of public swimming and recreational-use areas in inland waters based on the results and recommendations of this project.

Nature, Scope, and Objectives of the Research

AWW bacteriological monitoring data have been used by municipalities, county agencies, universities, private companies and state agencies for detecting, sourcing and solving bacterial contamination in inland surface waters. Recent citizen monitoring efforts at public swimming areas have suggested significant differences in *E. coli* concentrations measured at the same site at different times of the day. Side-by-side monitoring by citizen monitors, agency personnel and private laboratory personnel have also yielded difference results. Recent research supports these citizen monitoring results (see Related Research).

The research proposed in this project is aimed at determining the temporal and spatial distribution of bacterial contamination at public swimming areas in three recreational-use areas at lakes Logan Martin and Martin, as well as developing recommendations that best protect the public health for swim-area monitoring protocols for inland waters.

The objectives of this project are to:

1. sample multiple public swimming/recreational-use areas for bacterial contamination on two major reservoirs, one in the Tallapoosa Basin (Lake Martin) and one in the Coosa Basin (Lake Logan Martin) throughout the outdoor recreational season;
2. sample these same sites multiple times during the same day (morning, midday-afternoon) to evaluate temporal differences within the same day to examine the relationship between sediment *E. coli* counts and the surface water *E. coli* counts;
3. sample swim beach sediments to test for the presence of *E. coli*, and to test for other fecal bacteria (*Salmonella*);
4. conduct additional side-by-side AWW volunteer monitor bacteriological testing and agency testing, and;
5. test for sourcing of *E. coli* using selective antibiotic disks on bacterial media cultures.

Methods, Procedures, and Facilities

I. Conducting Bacteriological Sampling at Public Swimming Areas

A. AU Coliscan Easygel Sampling

The Coliscan Easygel method employed by the AWW Program was used for water monitoring of *E. coli* (Alabama Water Watch, 2012). Sampling sites were at public swimming/recreation areas on lakes Martin and Logan Martin, sites that have a history of AWW citizen/state agency monitoring (Table 1; Figure 1). Two samples were taken at each sampled beach – one on the left side and one on the right side of the beach.

Table 1. Sample sites at public swimming areas at Lake Logan Martin (Site 1 at Lakeside Park at Cropwell and Site 2 at Camp Cosby near St Ives, AL) and at Lake Martin (Site 3 at Wind Creek State Park near Alexander City, AL).

AWW Site	Lake	AWW Monitoring Group	Site Location	County	Lat (N)	Lon (W)
07001021	Lake Martin	Lake Watch of Lake Martin	Wind Creek State Park swim area	Tallapoosa	32.8564	85.9251
05012028	Logan Martin	Logan Martin Lake Protection Association	Camp Cosby (YMCA camp)	Talladega	33.4425	86.2782
05012046	Logan Martin	Logan Martin Lake Protection Association	Pell City Lakeside Park swim area	Saint Clair	33.5460	86.2689

Water samples were collected using a sterile pipette to collect one ml of water that will be discharged into a *Coliscan Easygel* media bottle. Sampling was done in triplicate at each site per the AWW EPA-approved QA plan. Samples were placed in a cooler with ice to prevent bacterial replication until samples could be plated. Plating was done after transport of samples back to the AWW laboratory if this could be accomplished within three hours of sample collection. Otherwise, samples were plated in the field and incubated in a portable incubator so that they were plated within a three-hour holding time. On a given sample date, each site was sampled two times – morning and midday/afternoon.

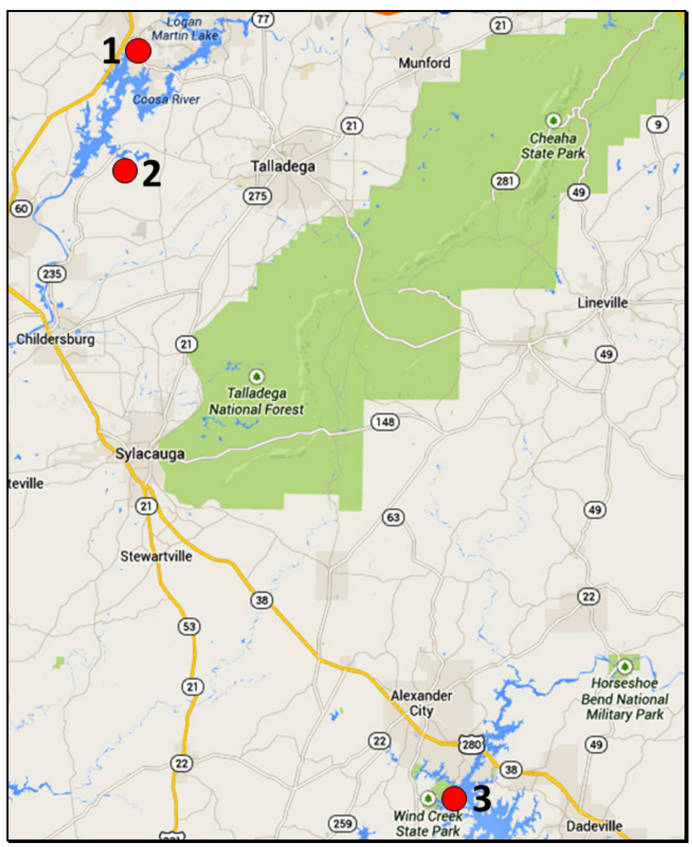


Figure 1. Sample sites on lakes Logan Martin and Martin.

B. Enumeration of *E. coli* and *Salmonella*

To correlate the AWW Coliscan Easygel method with FDA microbial enumeration methods, 50 ml of water sample or 25 g of sediment sample was collected using sterile disposable long-handled dippers at each sampling site each time (USFDA 2013). The samples were kept on ice and delivered to Wang's microbiology lab located on Auburn campus. Each water sample was vortexed for 2 min before six milliliters of water was picked and plated on to two 3M™ Petrifilm™ E.coli/Coliform count plate, two MacConkey agar and two XLT4 agar (1ml for each plate). After plating, 25 ml of the same water sample got enriched with 225 ml of lactose broth. Those enriched samples were plated only if on colony was found from the Petrifilm or the MacConkey or the XLT4 plate. For sediment samples, 100 ml of autoclaved MilliQ water was added to each 25 g sediment sample, and the samples were homogenized for 2 min before plating. The same plating procedure was followed as described above for water samples. Plates were incubated at 37°C for 24 hours before enumeration. Once suspected pathogenic E. coli and Salmonella isolates were found, they were sent to Iowa State University for serotyping.

C. Antibiotic Resistant Analyses

To understand the potential antibiotic resistant properties the isolates may have, one hundred microliters of each confirmed *E. coli* or *Salmonella* isolate was plated onto Mueller Hinton plates. The plates were divided into four quarters and appropriate antibiotic disks were placed on the surface of each quarter (Table 2). Plates were then incubated at 37°C for 18 hours and the resistant zone was measured.

Table 2. Antibiotic disks used in the antibiotic resistant tests.

Class	**Antibiotics**	**Disk concentration**
Penicillin	Amoxicillin-clavulanic acid	20µg
Penicillin	Ampicillin	10 µg
Cephalosporin	Ceftriaxone	30µg
Cephalosporin	Cephalothin	30 µg
Phenicol	Chloramphenicol	30 µg
Quinolone & Fluoroquinolones	Ciprofloxacin	5 µg
Cephalosporin	Cefoxitin	30 µg
Cephalosporin	Ceftiofur	30 µg
Aminoglycoside	Gentamicin	10 µg
Quinolone & Fluoroquinolones	Naladixic acid	30 µg
Sulfonamide	Sulfamethoxazole/Trimethoprim	23.75/1.25 µg
Tetracycline	Tetracyline	30 µg

D. AWW Citizen Monitoring

AWW-certified citizen monitors conducted concurrent monitoring during the project. AWW Program personnel oriented citizen monitors in the project goals, protocols and QA/QC plan prior to field data collection. Lake Watch of Lake Martin and Logan Martin Lake Protection Association volunteer monitors that had been trained and certified in AWW's Bacteriological Monitoring protocols sampled alongside AU researchers. It was not possible to coordinate with Alabama Department of Environmental Management personnel to conduct coincident sampling at select sites on the same date at the same time, but coincident sampling was coordinated with the City of Pell City personnel when possible.

II. Analysis of Bacterial Sampling Results

Concentrations of *E. coli* measured in the water column was interpreted relative to human health by comparison with USEPA and Alabama Department of Environmental Management water quality criteria (USEPA 2012; ADEM 2012). Water column and sediment bacteria (*E. coli, Salmonella*) data was compiled and analyzed for significant differences relative to time of day, testing procedure, and level of human/animal activity using SAS/STAT Software (Schlotzhauer and Little 1991). Bacteria data was analyzed to examine relationships/correlations among water column bacterial concentrations, sediment bacterial concentrations, time of day and human activity levels.

III. Facilities

Project bacteriological analyses were conducted in the Alabama Water Watch Watershed Stewardship Laboratory in the Center for Advanced Science, Innovation and Commerce located in the AU Research Park, and Dr. Wang's laboratory in the Animal Sciences Building on the main AU campus.

Results

Salmonella Monitoring:

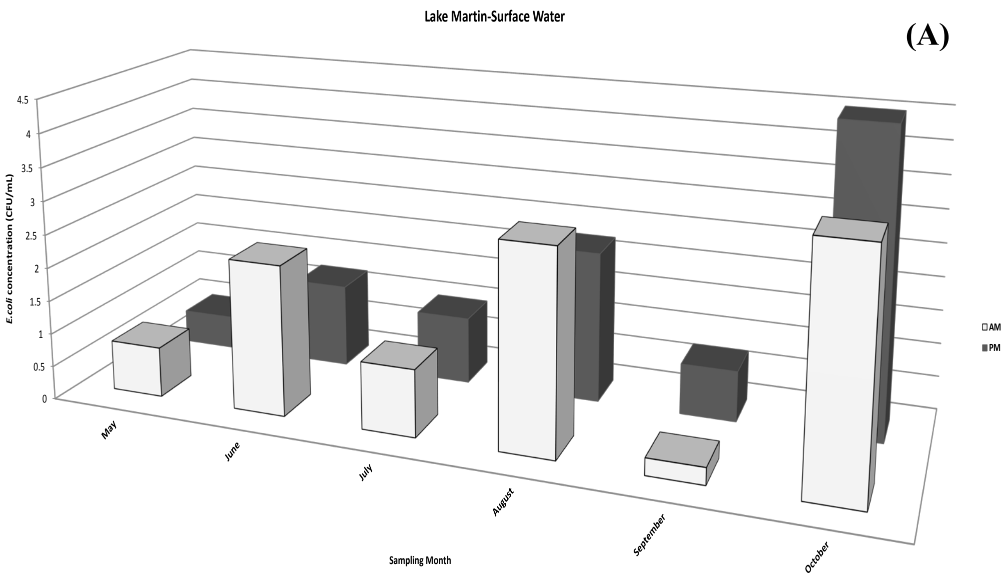
Twenty-five g of each sediment sample was weighed and 25 ml of each surface water sample was measured out. Samples were enriched in 225 ml 1× Lactose broth for 24 hours and the enriched broth was streaked onto XLT4 agar and incubated at 37°C for an additional 24 hours. Suspect *Salmonella* colonies were checked the next day. *Salmonella* tests were done for all of the 24 samples collected on May 1st 2014. However, no suspect *Salmonella* colony was seen on XLT4 plates. *Salmonella* was not found in the water or the sediment samples, therefore the research team decided to discontinue the *Salmonella* testing starting from the second sampling time (June 4th 2014).

One phenomenon that is worth mentioning is that on June 4th 2014, a Canada goose fecal sample was collected from Wind Creek. This sample was enriched and plated, suspect *Salmonella* colonies were seen on the selective agar from this particular sample. According to the literature, wild animals can carry *Salmonella* at a level of approximately 10% (Silva-Hidalgo et al., 2013), thus retrieving *Salmonella* from goose feces was not unusual. However, *Salmonella* was not detected in the water. Our hypothesis is that wild animals can have *Salmonella* in their feces; however, if *Salmonella* is present in low concentrations, it will not survive long in the environment (water) and will not pose a human health risk after it is outside of the animal's body. Of note was the extremely high count of *E. coli* bacteria in the fecal sample, indicating that Canada geese can be a significant contributor to *E. coli* contamination of surface waters.

***Escherichia coli* Monitoring:**

A. Standard Methods Monitoring – Temporal Comparison

A total of six sampling trips were made from May 2014 to October 2014. Three sampling sites were chosen at the beginning, one was dropped after August due to issues with access. Lake Martin and Lake Logan Martin are the two lakes from which data will be presented in this report. As shown in Figure 2 (A, below), season (in other words, temperature, rain fall, etc.) played significant role in *E. coli* concentrations in surface water. The *E. coli* concentrations of Lake Martin in the afternoons were not significantly different from the morning samples (T-test, $P > 0.05$). For Lake Logan Martin, from the month of May to August, the concentrations of *E. coli* in the afternoon samples were significantly higher than the morning samples. In September and October, the morning samples contained higher concentrations of *E. coli* than the afternoon samples. However, if all of the *E. coli* samples from all six sampling months are analyzed collectively, there is no significant difference between morning and afternoon *E. coli* concentrations (T-test, $P > 0.05$). The occasional differences seen in *E. coli* counts in Lake Logan Martin between morning and afternoon samples might be caused by disturbance of sediments from swimming and other beach activities.



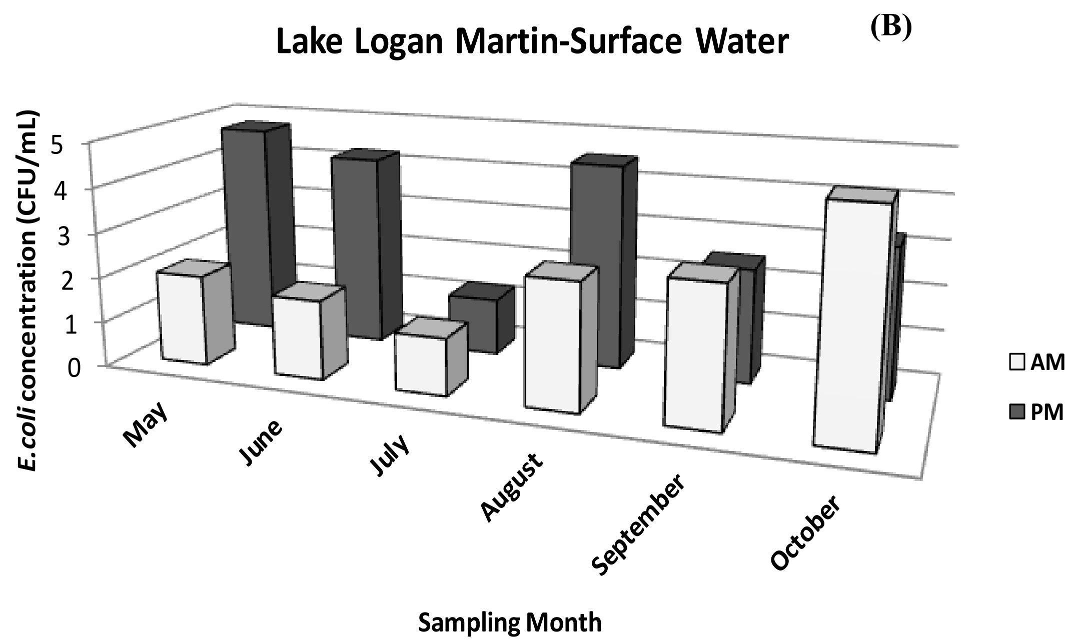
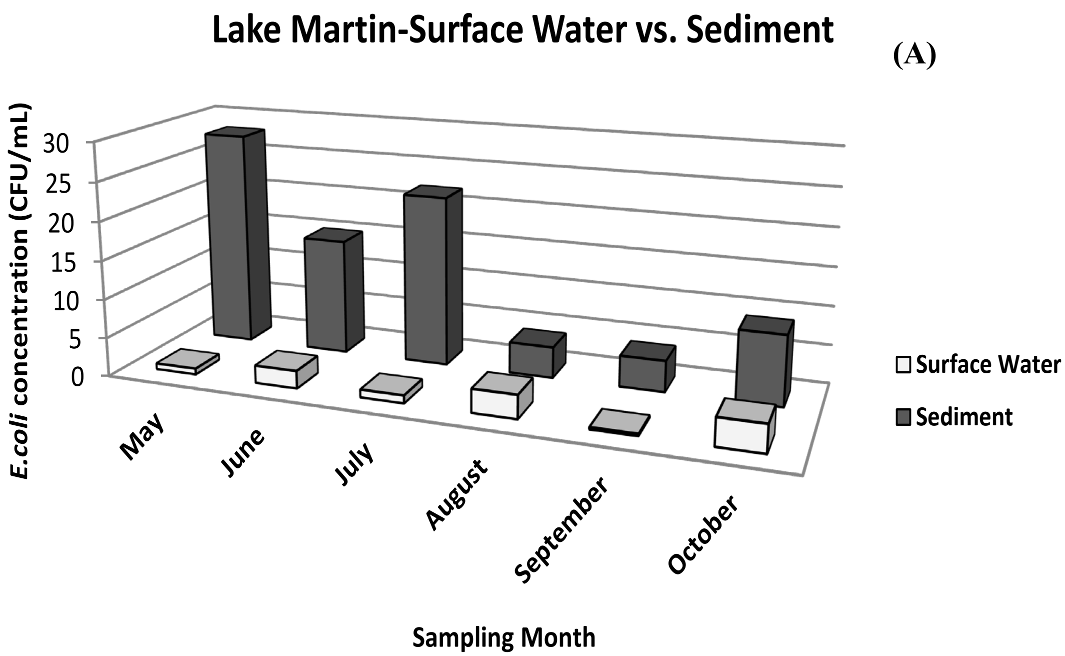


Figure 2. Concentrations of *E. coli* in surface water samples collected from Lake Martin (graph A) and Lake Logan Martin (graph B). Two sampling times were conducted for each trip, one in the morning when human activities were minimal and one in the afternoon when most activities occurred.

B. <u>Standard Methods – Comparison of *E. coli* Concentrations in Water versus Sediment</u>

As shown in Figure 3 (below), regardless of the sampling month or the lake, *E. coli* concentrations were always significantly higher in the sediments samples (T-test, $P > 0.05$). This phenomenon may help to explain the *E. coli* surface water concentration differences happening between morning and afternoon samples. Swimming and other activities can resuspend some of the *E. coli* cells from the sediment into the surface water.



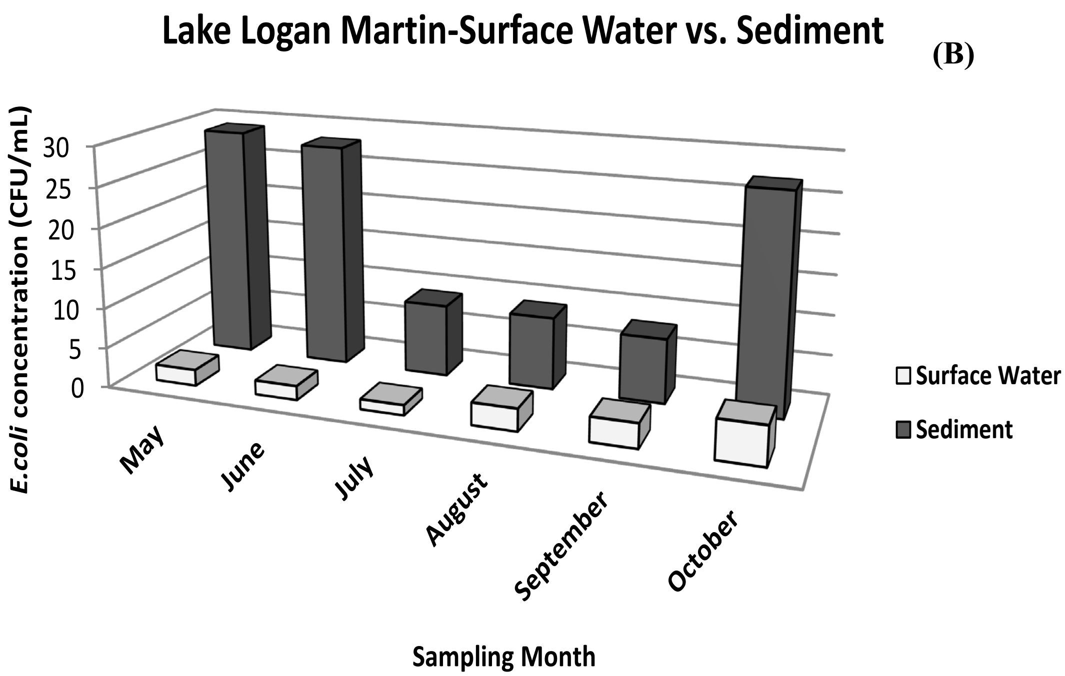


Figure 3. Concentrations of *E. coli* in surface water vs. sediment from Lake Martin (graph A) and Lake Logan Martin (graph B) (sediments were sampled during morning sampling only).

C. AWW Methods Results of AU Personnel versus AWW Volunteers

AWW staffers (AU Water Resources Center personnel) sampled side-by-side AWW volunteer monitors of Lake Watch of Lake Martin at the Wind Creek sample site and AWW volunteer monitors of Logan Martin Lake Protection Association at the Lake Side and Camp Cosby sites. All volunteer monitors were certified by AWW for bacteriological monitoring. Both AU personnel and AWW volunteer monitors followed AWW's EPA-approved bacteriological monitoring protocol, using Coliscan Easygel media and petri dishes.

Results are shown below (Figure 4). Side-by-side results were analyzed using T-tests. In all cases at all sites, AU and AWW volunteer monitor results of *E. coli* levels in surface waters at the three swim areas were not significantly different samples (T-test, $P > 0.05$), except for a single instance at Camp Cosby (on 7/8/2014: AU *E. coli* count per petri dish = 0,0,0,0,0,0; AWW *E. coli* count per petri dish = 0,1,0,1,1,1). Thus, out of 16 side-by-side sample events, AU and AWW results of *E. coli* levels were not significantly different 15 of 16 times, or 94% of the time.

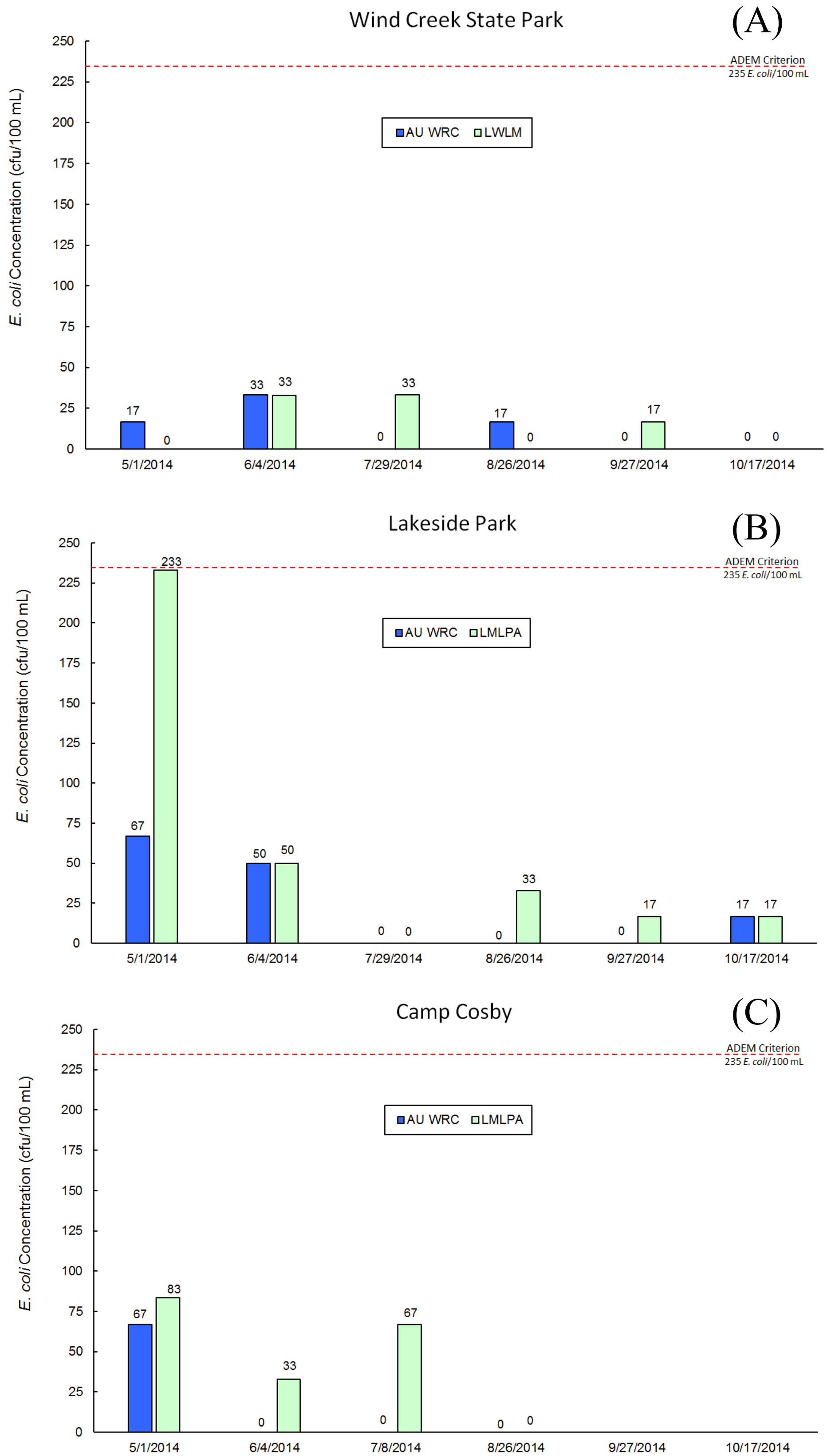


Figure 4. Concentrations of *E. coli* in surface water from Lake Martin (graph A) and Lake Logan Martin (graphs B, C) measured by AU personnel (blue bars) and AWW volunteer monitors (green bars).

D. Comparison of AU, AWW Volunteer and Pell City Results:

The City of Pell City sampled side-by-side the AU personnel and LMLPA volunteer monitors on three different sample dates in May, June and July. The City conducts routine bacteriological monitoring on a weekly basis at the Lakeside Park swimming area in collaboration with Logan Martin Lake Protection Association. Water samples are delivered to a private laboratory for analyses. Results are presented below (Figure 5).

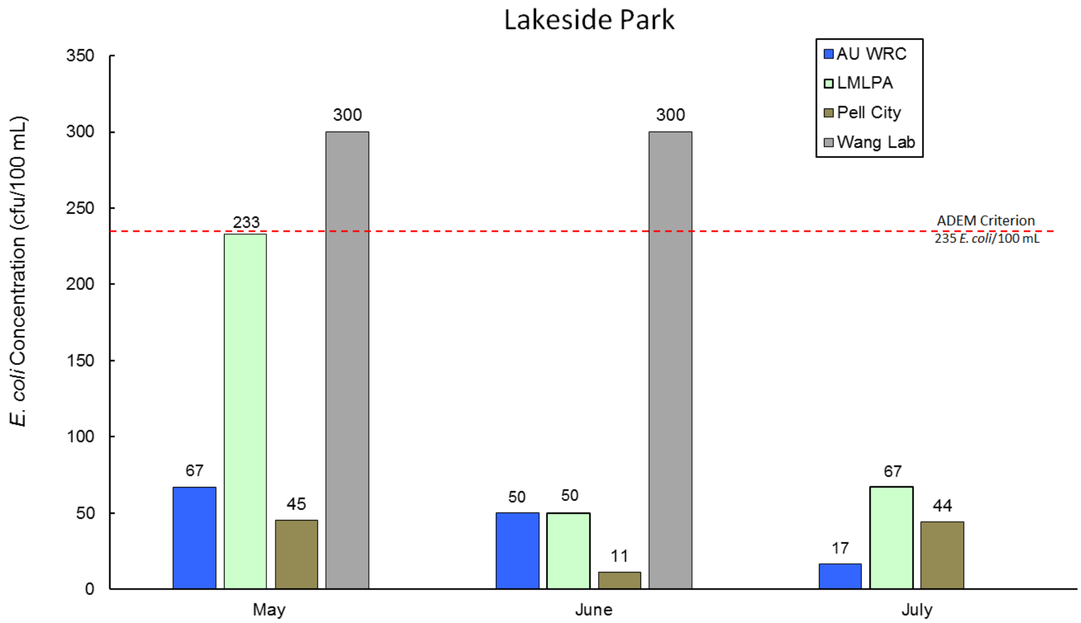


Figure 5. Concentrations of *E. coli* in surface water from Lake Logan Martin (graph B) measured by AU personnel (blue bars), Logan Martin Lake Protection Association volunteer monitors (green bars), Pell City (brown bars) and Wang lab (grey bars).

Results indicate that:

1. Even with side-by-side sampling, bacterial concentrations are not evenly distributed in the sampled environment (lake water), in other words, there is significant variability among samples even on the same date and time.
2. In general, lakeside plating yielded lower *E. coli* concentrations.
3. Agreement was best between AU Water Resources sampling and City of Pell City sampling (mean of three events was 44.5 cfu/100 ml and 33.3 cfu/100 ml, respectively).

E. Correlation between *E. coli* Concentration and Number of Waterfowl Present:

Researchers conducted visual observations and counts of the number of waterfowl present at each sampling location each date-and-time the location was sampled. Enumeration of waterfowl along with *E. coli* concentrations (mean of left-beach and right-beach sample taken by AU Water Resources personnel) are presented below (Table 3.)

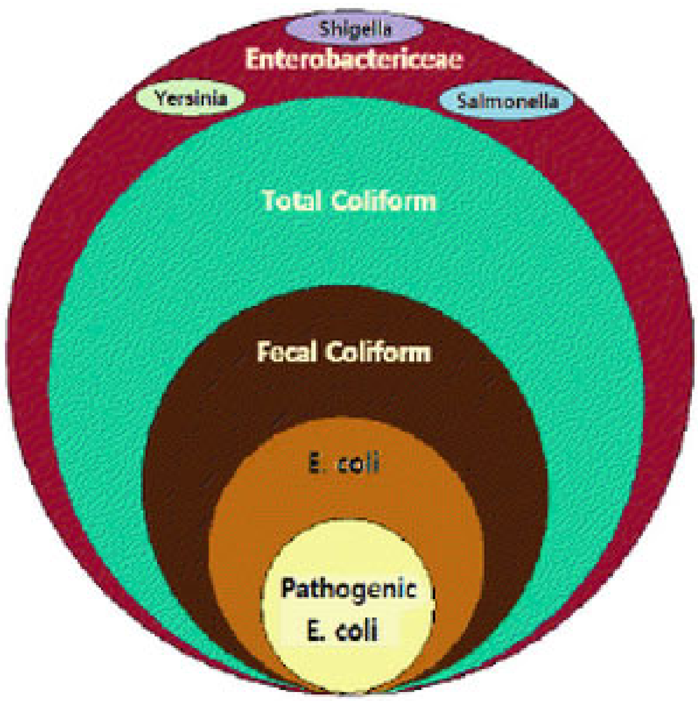
Table 3. Number of waterfowl present at sample sites and associated *E. coli* concentration in the surface water.

Location	Date	Time	N	*E.coli*	Fowl
Camp Cosby	05/01/14	After	2	150.0	0
Camp Cosby	05/01/14	Morn	2	66.5	0
Camp Cosby	06/04/14	After	2	0.0	0
Camp Cosby	06/04/14	Morn	2	16.5	0
Camp Cosby	07/08/14	After	2	0.0	0
Camp Cosby	07/08/14	Morn	2	0.0	0
Camp Cosby	08/26/14	After	2	0.0	0
Camp Cosby	08/26/14	Morn	2	0.0	0
Lakeside	05/01/14	After	2	100.0	0
Lakeside	05/01/14	Morn	2	66.5	0
Lakeside	06/04/14	After	2	50.0	10
Lakeside	06/04/14	Morn	2	50.0	2
Lakeside	07/29/14	After	2	16.5	0
Lakeside	07/29/14	Morn	2	0.0	0
Lakeside	08/26/14	After	2	67.0	0
Lakeside	08/26/14	Morn	2	0.0	0
Lakeside	09/27/14	After	2	0.0	0
Lakeside	09/27/14	Morn	2	0.0	3
Lakeside	10/17/14	After	2	16.5	0
Lakeside	10/17/14	Morn	2	16.5	0
Wind Creek	05/01/14	After	2	16.5	18
Wind Creek	05/01/14	Morn	2	0.0	.
Wind Creek	06/04/14	After	2	33.0	40
Wind Creek	06/04/14	Morn	2	100.0	30
Wind Creek	07/29/14	After	2	0.0	0
Wind Creek	07/29/14	Morn	2	0.0	0
Wind Creek	08/26/14	After	2	16.5	0
Wind Creek	08/26/14	Morn	2	16.5	0
Wind Creek	09/27/14	After	2	0.0	0
Wind Creek	09/27/14	Morn	2	0.0	3
Wind Creek	10/17/14	After	2	0.0	0
Wind Creek	10/17/14	Morn	2	0.0	0

Correlation analyses revealed that there was no significant correlation between *E. coli* concentrations in the surface water and number of waterfowl observed at a sample site ($P > 0.05$).

Enterobacteriaceae Monitoring:

The family Enterobacteriaceae encompasses approximately 20 genera, including *E. coli* and all members of the coliform group; as well as foodborne pathogens *Salmonella, Shigella, and Yersinia*. The family was originally proposed as an indicator alternative to the coliform group because testing for the entire family would be more inclusive for the pathogenic bacteria. The Enterobacteriaceae may be superior to coliforms as indicators of sanitation GMPs because they have collectively greater resistance to the environment than the coliforms. This group is more widely used as indicators in Europe than in the United States (see www.mybiolumix.com/the-debate-coliforms-fecal-coliforms-and-enterobacteriaceae-as-indicator-organisms).



The protocol of preparing, plating, and enumerating Enterobacteriaceae is the same with *E. coli*, except 3M Petrifilm™ Enterobacteriaceae plates were used instead of 3M Petrifilm™ *E. coli* plates.

As shown in Figure 6(A) below, no significant difference was seen between the morning and afternoon samples collected in Lake Martin (T-test, $P > 0.05$). For Lake Logan Martin (graph B), the afternoon samples contained significantly higher numbers of Enterobacteriaceae than the morning samples for May and August, while the morning samples contained slightly higher numbers of Enterobacteriaceae than the afternoon samples for September and October.

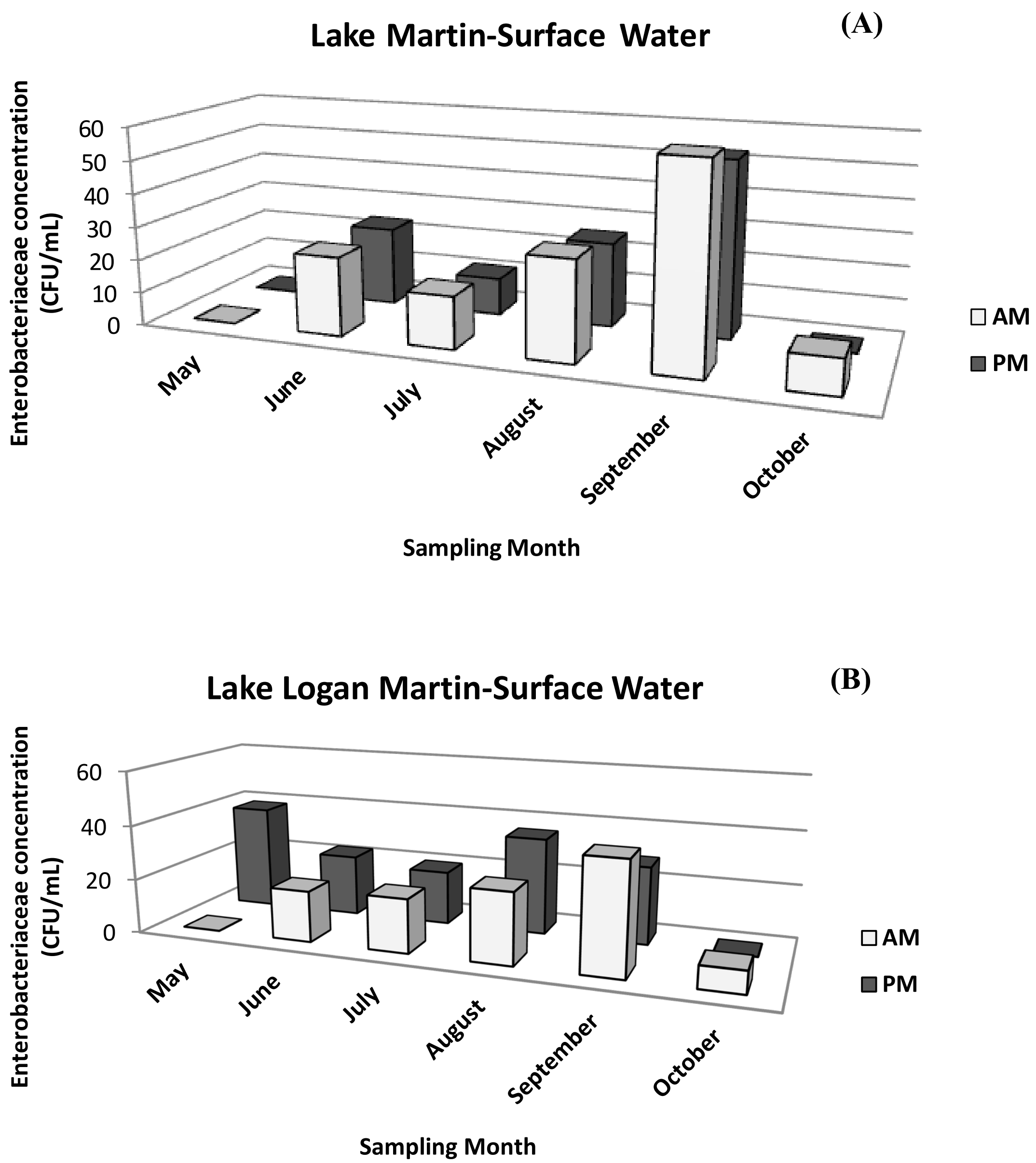
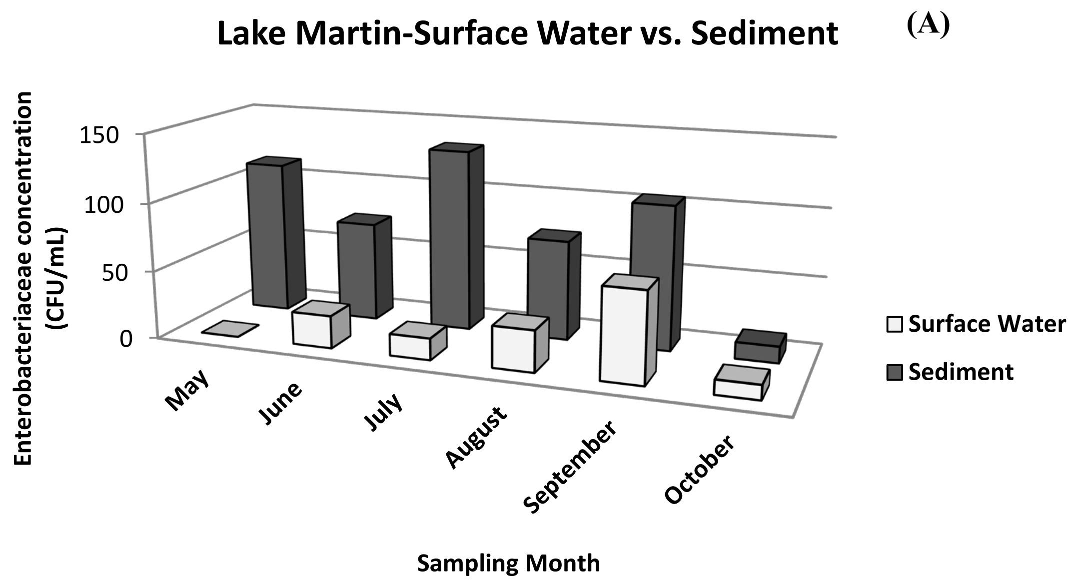


Figure 6. Concentrations of Enterobacteriaceae in surface water samples collected from Lake Martin (graph A) and Lake Logan Martin (graph B) in the morning vs. in the afternoon.

As shown in Figure 7 below, regardless of the sampling month or the lake, concentrations of Enterobacteriaceae were significantly higher in the sediments compared to the surface water (T-test, $P > 0.05$). In addition, the differences between surface water vs. sediments in Lake Martin were greater compared to the differences existed between surface water vs. sediment in Lake Logan Martin. In Lake Martin we saw several geese, and some also at Logan Martin, and collected one goose fecal sample that tested positive for *Salmonella*. Enterobacteriaceae can indicate the potential presence of *Salmonella* and *Shigella*, thus, higher Enterobacteriaceae may correlate to a higher probability of *Salmonella* in the water, though we did not detect any *Salmonella* in water samples that we tested.



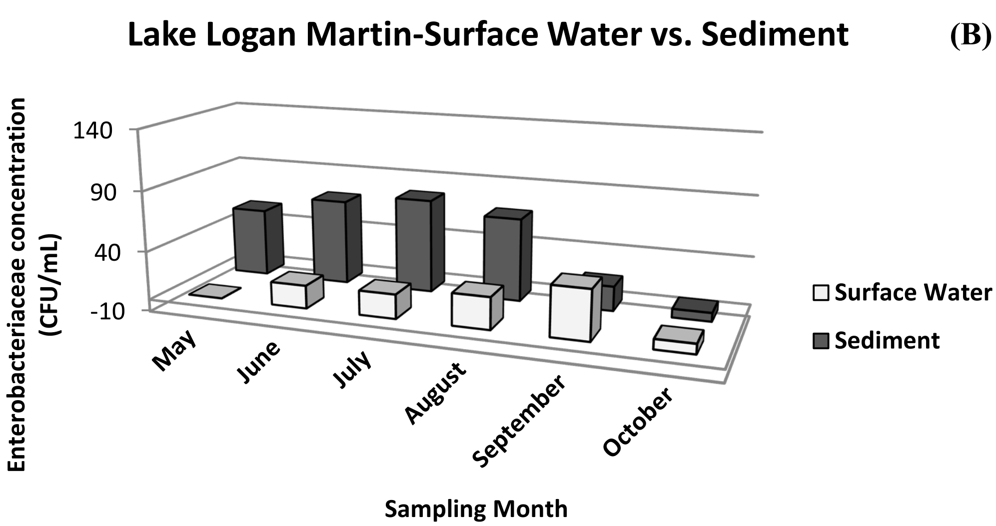


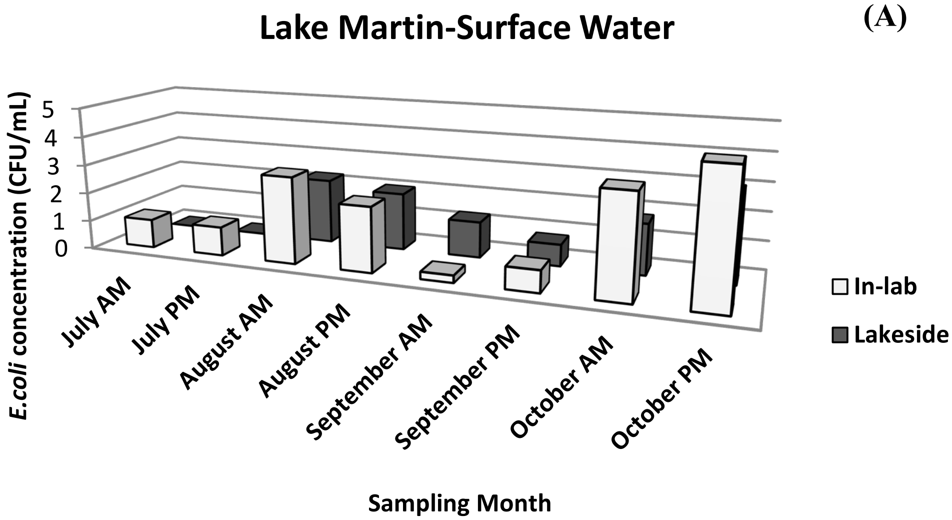
Figure 7. Comparison in Enterobacteriaceae concentrations between surface water and sediments collected from Lake Martin (graph A) and Lake Logan Martin (graph B).

Sampling Technique Comparison:

Due to the differences we saw between the EasyGel method results and the Petrifilm method results, we proposed that sampling technique differences could be one of the reasons that caused discrepancies in test results. To test this hypothesis, parallel comparisons were conducted. The student collected two 1-ml surface water samples from the lake and directly plated on Petrifilm plates on site and incubated them in the lab. The student also collected water samples ~50 ml or ~50 g of sediments and conducted the preparation and plating after she came back to the lab. Results from the Alabama Water Watch method, referred to as 'Lakeside' plating, while the *Standard Methods* method, referred to as 'In-lab' plating are presented in Figure 8 below.

As shown in Figure 8, regardless of the sampling month, sampling time (AM vs. PM), or sampling site, the in-lab plating yielded relatively higher counts compared to lakeside plating. One explanation is that in-lab plating deals with larger sample sizes and the vortex step gave a more even distribution of the *E. coli* in that 1 ml plated sample. Another possible explanation is that the in-lab plating allowed possible reproduction of bacterial cells in transit because of the longer holding time of media before plating. Nonetheless, based on statistical analysis, no significant difference was detected between these two different sampling methods with regards to *E. coli* counts obtained ($P > 0.05$).

(A)



(B)

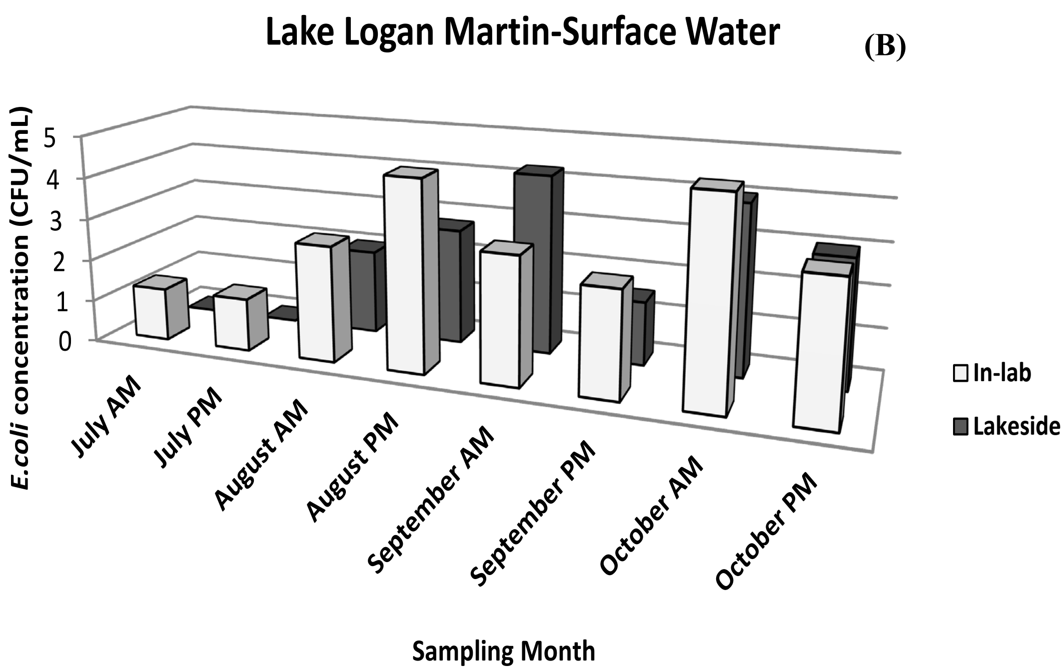
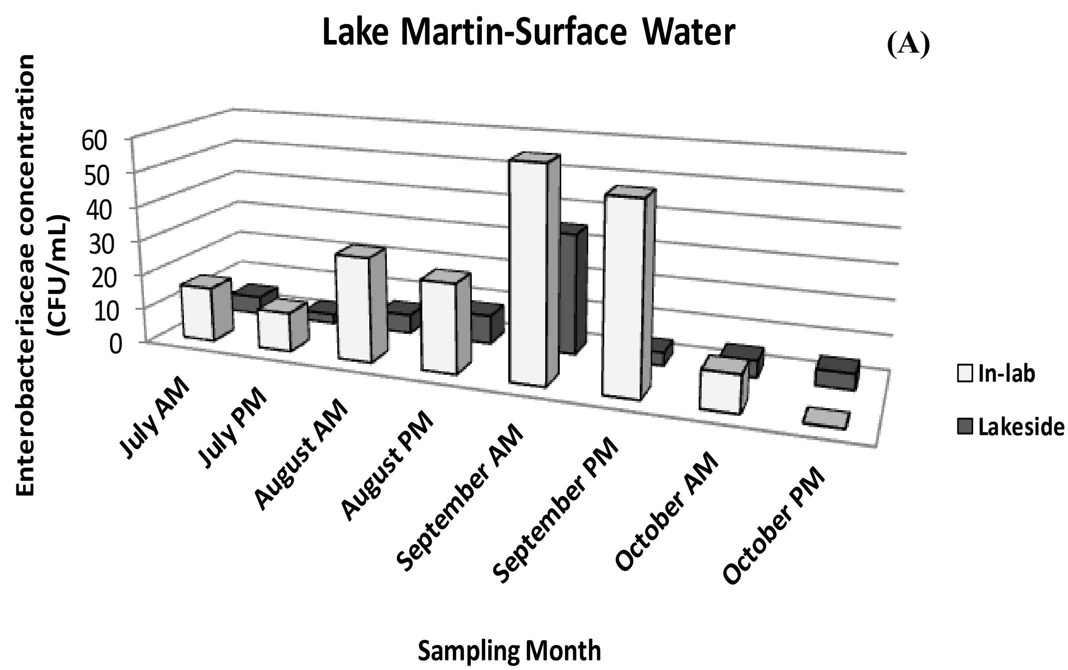


Figure 8. Comparison of lakeside plating vs. in-lab plating (*E. coli* concentrations).

As shown in Figure 9 below, with higher Enterobacteriaceae concentrations (relative to *E. coli* concentrations), it is more evident that the in-lab plating gave higher counts than the lakeside plating method. Results of the statistical analysis indicated that the two sampling methods for Enterobacteriaceae yielded significantly different counts ($P < 0.05$).



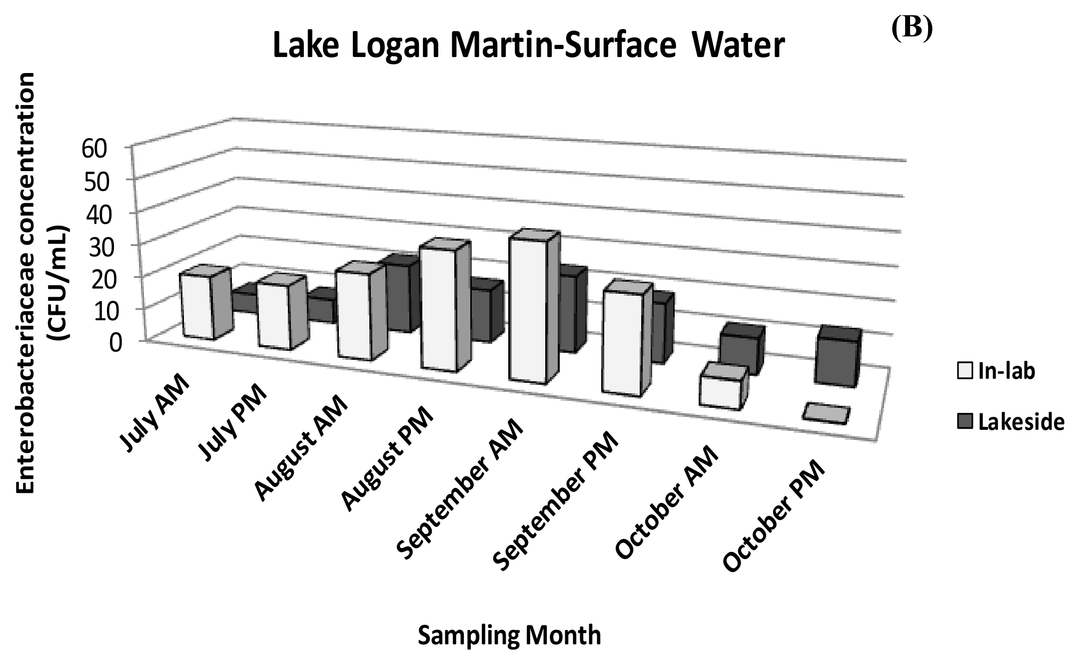


Figure 9. Concentrations of Enterobacteriaceae using different plating methods (Enterobacteriaceae).

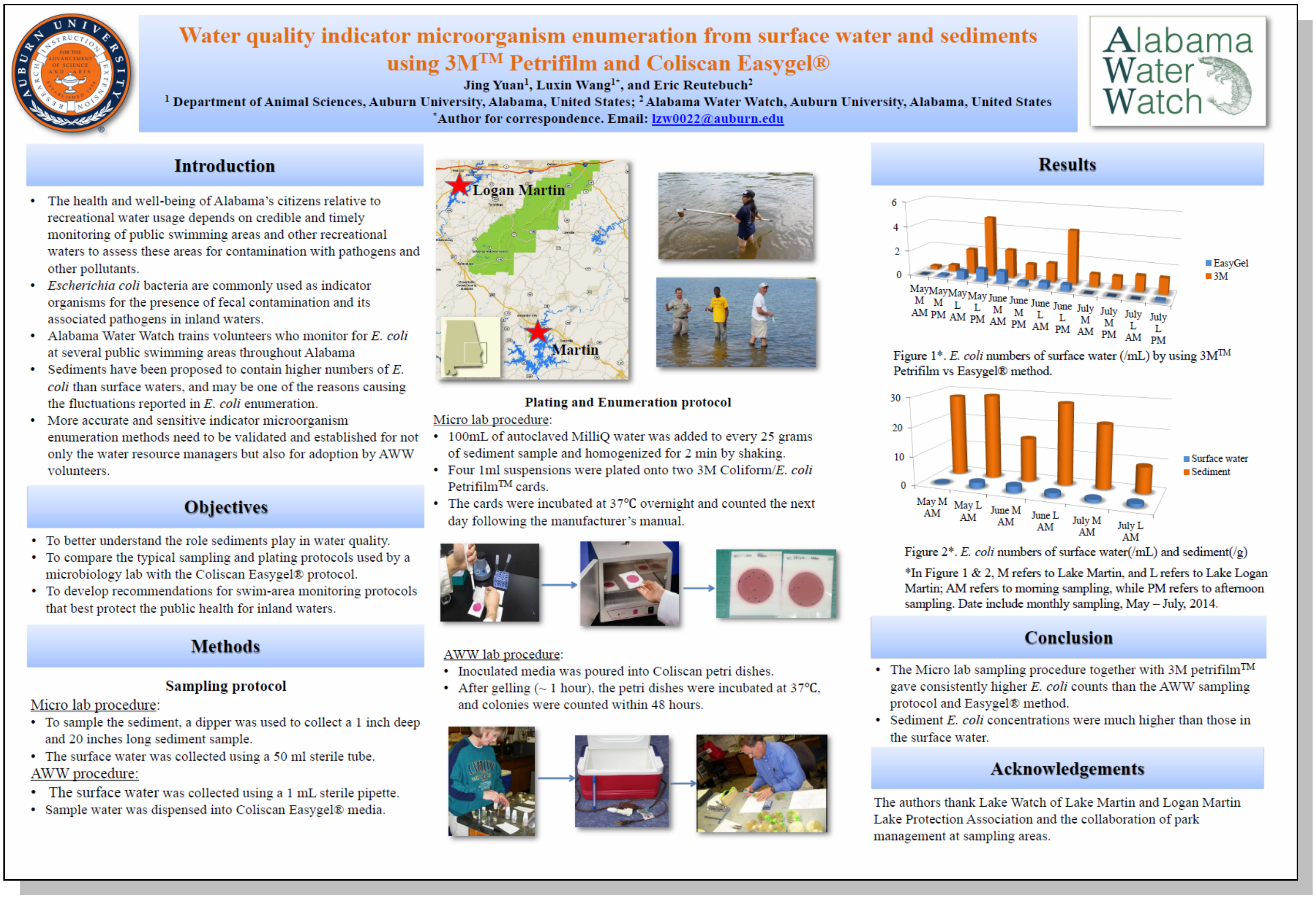
Outreach

Project results were communicated to Wind Creek State Park officials at a meeting at the park, and in an article published by Tallapoosa Publishing Company in the January 2015 issue of Lake Magazine (see Appendix).

Project results (as of 7/2014) were communicated to the Logan Martin Lake Protection Association during a presentation at the Pell City Civic Center on July 17, 2014 (see below).

Project results from the Logan Martin sample site at Lakeside Park were presented at the ADEM Nonpoint Source Conference on January 15, 2015 in Montgomery, AL (see slides below).

Project results were also communicated in a poster presentation at the 2014 Alabama Water Resources Conference on September 4, 2014 in Orange Beach, AL (see poster below).



Conclusions

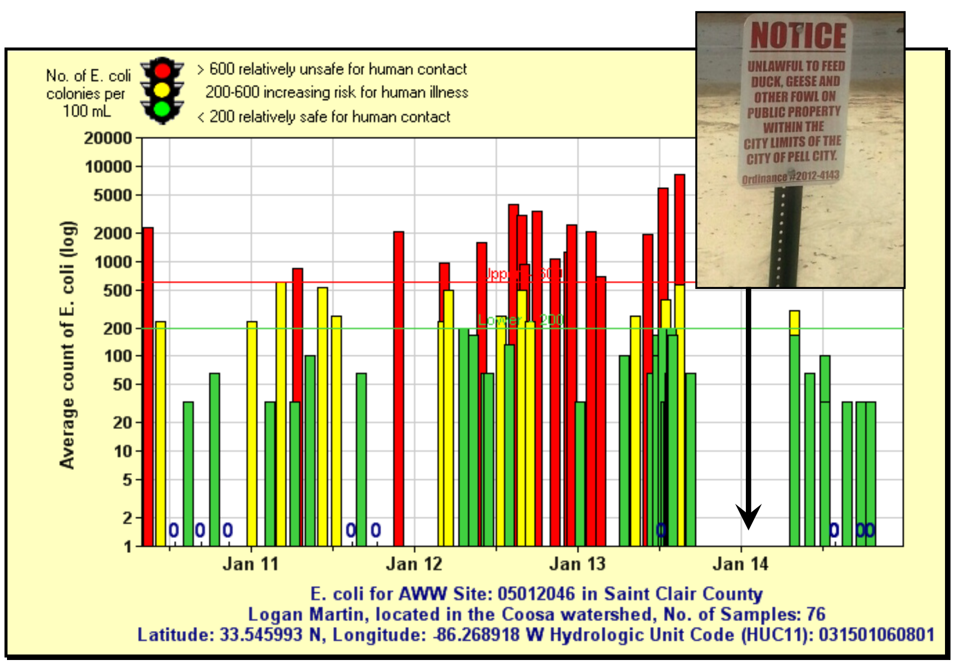
1. *E. coli* concentrations were sometimes significantly different when sampling the surface water at different times of the day.
2. Enterobacteriaceae is present in lake water in much higher numbers than *E. coli* and has a potential to be used for lake water monitoring as it includes more pathogens like *Salmonella* and *Shigella* than coliform and *E. coli* tests.
3. Both *E. coli* and Enterobacteriaceae were present in significantly higher numbers in the sediments than the surface water.
4. Although there was no significant correlation between the number of waterfowl observed at each beach and the concentration of *E. coli* present in the water ($P > 0.05$), Canada goose feces was found to test positive for *Salmonella* and high levels of *E. coli*.
5. Differences were observed in the AWW *E. coli* 'lakeside' sampling and plating method, which routinely yielded lower counts, compared to the FDA microbial enumeration method (plating back in the lab); although the differences were not significant ($P > 0.05$).

Differences in the two methods were significant for Enterobacteriaceae enumeration (*P > 0.05*). Possible reasons for these differences may be:

a. Replication of Enterobacteriaceae may occur during the transport back to the lab (FDA microbial enumeration method) because of longer holding time or due to the fluctuations of the internal temperature of the holding cooler,
b. Increased probability of sampling Enterobacteriaceae from the environment using the standard method procedure because of the much larger sample volume used (50 ml versus 1 ml).

Recommendations

1. Because of uneven distribution of bacteria in the aquatic environment, replicate sampling (preferably triplicate sampling) is recommended for bacteriological monitoring of surface waters.
2. Results from Enterobacteriaceae sampling suggests that this group of bacteria (which includes Enterococcus) may be a more sensitive bacterial indicator for fecal contamination of surface waters. Further study is recommended.
3. Since Canada goose feces contains both *Salmonella* and high levels of *E. coli*, avoid feeding water fowl at public swimming areas. It is recommended that signage be posted (see image below) and local ordinances be passed to restrict the feeding of water fowl at public swimming areas, as was done at the Lakeside Park swimming beach. The impact was very dramatic in curtailing *E. coli* contamination at the beach – only on one instance was the concentration of *E. coli* above 235/100 ml (on 5/1/2014 the concentration was 300 *E. coli*/100 ml), see graph below.



Source: https://fp.auburn.edu/icaae/ddBacHistory.aspx?dg=1&GroupName=LoganMartinLakeProtectionAssociation&AwwSiteCode=05012046&ChartID=6

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APPENDIX: Letters of Support from Collaborating AWW Water Monitoring Groups and Publication about the Project

- **Letter of Support from Logan Martin Lake Protection Association**
- **Letter of Support from Lake Watch of Lake Martin**
- **Lake Magazine article (January 2015 issue)**

QUANTITY QUALITY SAFETY
LMLPA
LOGAN MARTIN LAKE PROTECTION ASSOCIATION
P.O. Box 2002
Pell City, AL 35125

December 17, 2013

Dr. Luxin Wang
Department of Animal Sciences
210 Upchurch Hall
Auburn University, AL 36849

Dear Dr. Wang:

I am pleased to offer this letter of support for your program's Alabama Water Resources Research Institute (WRRI) proposal. Working with local nonprofit organizations to identify less expensive but meaningful methodologies that will assist in identifying pollutants of concern for water quality and aid in effective implementation of practices to improve water quality is a critical step in the long-term protection and restoration of Alabama waters.

Logan Martin Lake Protection Association has partnered with Alabama Water Watch on many occasions to implement outreach and research programs. Each program has been a success due to the highly qualified, technical professionals that lead your programs and the trust that has been built between Alabama Water Watch and stakeholders throughout the State of Alabama.

I have no doubt future funding of this WRRI project will result in improved techniques for assessing and monitoring water quality in Alabama. Importantly, results from this project will serve as a template for other groups around the state and region seeking to improve water quality.

Please contact me at (205) 525-5309 or mike.riley@lmlpa.org with any questions.

Sincerely,

Mike Riley
President
Logan Martin Lake Protection Association

Cc: AWW

www.lmlpa.org

LakeWatch
of Lake Martin

December 18, 2013

Dr. Luxin Wang
Department of Animal Sciences
210 Upchurch Hall
Auburn University, AL 36849

Dear Dr. Wang:

I am pleased to offer this letter of support for your proposal to conduct in-depth bacteriological monitoring at the Wind Creek State Park swimming beach in 2014. I understand this research would also include the use of volunteer monitors, including those associated with Lake Watch. As presented, this testing would monitor for *E. coli* and Salmonella, both in the water column and in the sand/sediment below the water at early morning and at mid-day/afternoon throughout the recreational season in 2014, then look at relationships between the sediment levels of bacteria and levels in the water column. Test results would allow for the development of recommendations for bacterial monitoring of inland swimming areas that are most protective of public health. These recommendations would then be disseminated to AWW volunteer monitors throughout Alabama and to state agency personnel who are involved in water quality monitoring.

Lake Watch of Lake Martin is delighted by this proposal and we are eager to participate. Recent concerns regarding *E. coli* and salmonella have been discussed by our monitors and we have been contacted regarding testing for bacteriological contaminants by local agencies. This proposal would help us develop better testing protocols and improve our volunteer water monitoring program. We fully support the project.

Please contact me at 256-825-2624 or khbraund@mac.com with any questions.

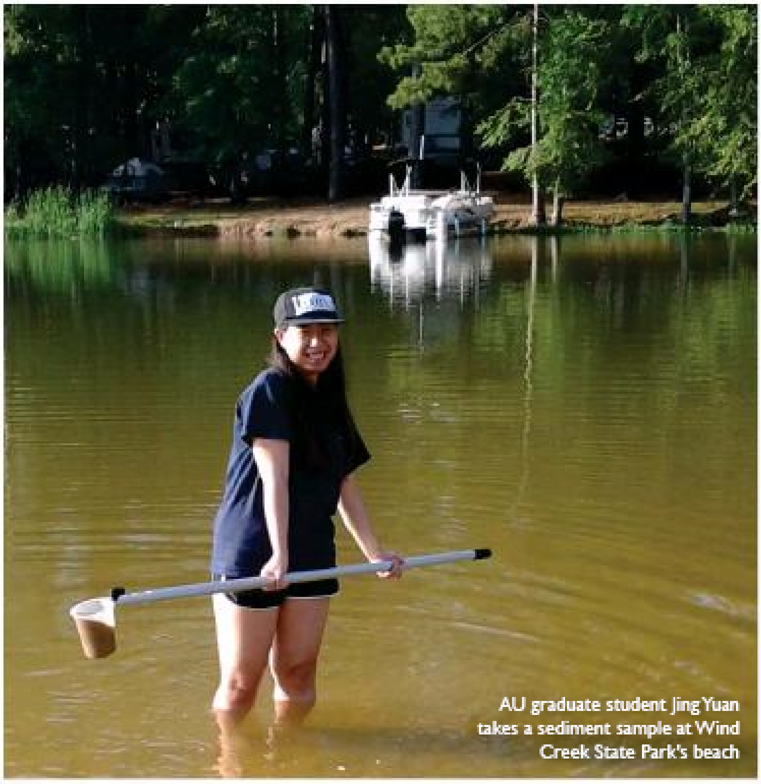
Sincerely,

Kathryn Braund

Dr. Kathryn H. Braund, President
Lake Watch of Lake Martin

P.O. Box 72 • Alexander City, Alabama • 35011 • 256-825-9353 • www.lakewatch.org

Lake Magazine, January 2015 issue.



AU graduate student Jing Yuan takes a sediment sample at Wind Creek State Park's beach

AWW Director Eric Reutebuch tests samples for E. coli bacteria

Lake Martin added to swim guide site

Extensive Auburn University study affords 100 percent rating for Wind Creek State Park Beach

STORY BY BETSY ILER
PHOTOS & GRAPH COURTESY OF AU WATER RESOURCES CENTER

Lake Martin's Wind Creek State Park Beach last month joined theswimguide.org website with a 100 percent rating as one of a handful of clean freshwater swimming beaches in the interior of Alabama. The post came after several months of vigorous chemical and bacterial water sample tests conducted through the Auburn University Alabama Water Watch (AWW) office in the AU Water Resources Center and local Lake Watch volunteers.

AWW Director Eric Reutebuch posted the results of the six-month testing program in mid-December, noting that bacterial levels remained well below harmful levels throughout the testing.

"Every time we sampled, the levels were well below the limit for E. coli," Reutebuch noted. "It was always well within the safe zone for human contact."

Levels under 200 E. coli colonies per 100 milliliters are deemed safe by AWW, with Alabama's Department of Environmental Management criteria at 235 E. coli colonies per 100 milliliters of lake water.

The samples taken from Lake Martin were never higher than 33 colonies per 100 milliliters, Reutebuch said.

The study was funded by the U.S. Geological Society through the Water Resources Research Institute. Research was conducted by Auburn University microbiologist Dr. Luxin Wang and her graduate student Jing Yuan, along with Lake Watch Lake Martin volunteer water quality monitors. Samples were taken from the site two times on one day each month from May through October, and test results can be found online at www.alabamawaterwatch.org.

"Click on water data; then, summary data and bacteria and site histories," Reutebuch said.

"One of the biggest things that came out of the study was getting Lake Martin onto theswimguide site," he added. "The guide lists swimming beaches from all over the U.S., Canada and Mexico. You can click on any site on the map and get a report of the cleanliness of that beach. There's an app for it, too, so you can check it on your smartphone."

In addition to taking water samples in the morning and afternoon, the testing team took sediment samples in the morning on testing days, as recent research has indicated there could be E. coli concentrations below the water, Reutebuch said. The teams dipped up the sediment on the lake floor after taking their morning samples; then, they returned to the site in the afternoon to take additional samples.

"In general, the sediment tested did have higher levels, but again in Lake Martin it was a non-issue. Levels were still substantially lower than limits," Reutebuch reported.

One other lake in Alabama was part of the study; Logan-Martin north of Lake Martin. While some water quality issues were identified there – and preventative actions taken as a direct result – Lake Martin's bacterial counts were never a cause of concern over the course of the testing program, Reutebuch said.

Another objective of the local testing program was to check and validate the procedures and test results of Lake Watch Lake Martin, said Ann Campbell, chair of water quality monitoring at Lake Watch.

"We took samples beside the Auburn testers, and we consistently had the same results," Campbell said.

The Lake Watch program this year added six volunteer monitors and nine sites to their program. The non-profit watchdog organization now includes 18 volunteers who take monthly water samples at 23 sites around Lake Martin, including the state park beach.

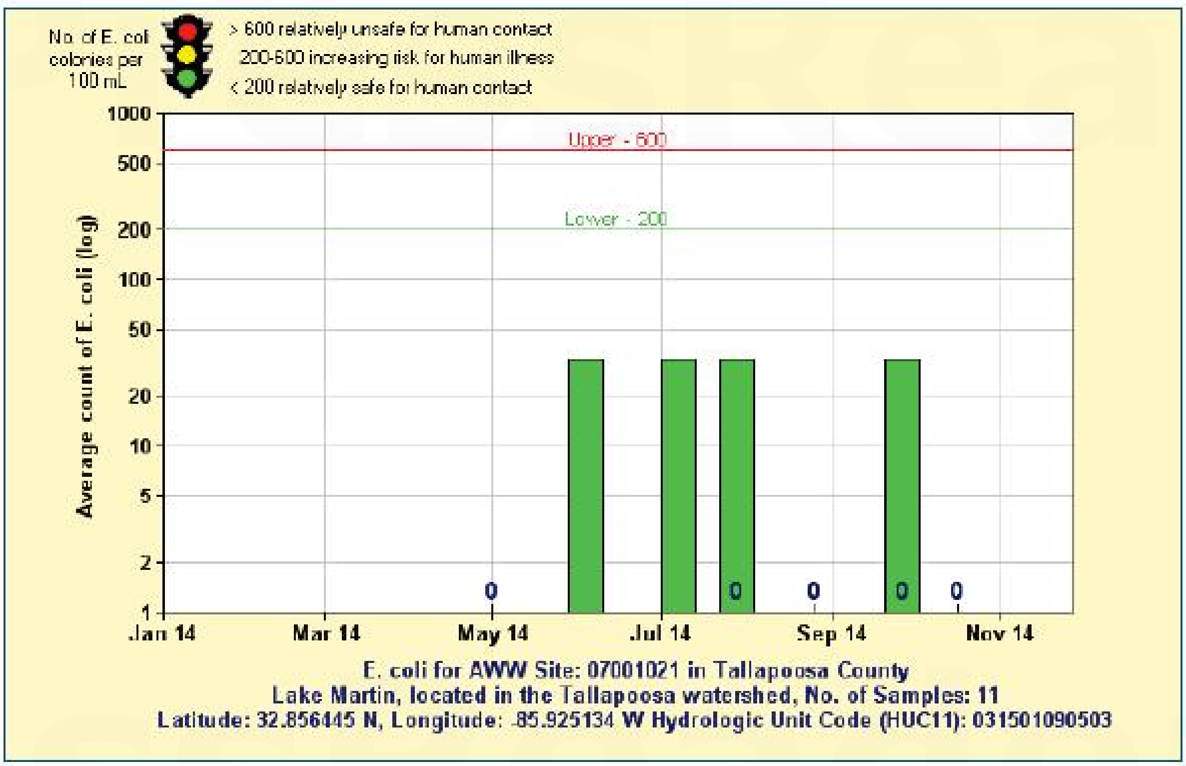
Lake Watch will continue to test the beach area and will post test results on theswimguide.org site, which also posts information of interest to visitors to the area.

Lake Watch Education Chair Dick Bronson said students in the gifted program at Alexander City's Radney Elementary School also have been sampling and testing water at the state park beach.

"This swim guide site has given them a practical application for something they have been doing in the classroom for three years. It is meaningful and useful as a public service," Bronson said.

Lake Watch hopes to add the D.A.R.E. Park beach to the program in the future, he added.

E. coli presence in samples is well below harmful levels



Water Policy and Law in Alabama

Basic Information

Title:	Water Policy and Law in Alabama
Project Number:	2014AL166B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	7
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, Water Use
Descriptors:	None
Principal Investigators:	Bennett Bearden, Heather Elliott

Publication

1. This project has produced a 345 page treatise on Alabama water resources law and policy with the following chapters: Alabama's Water Resources; Alabama's Ownership of and Regulatory Authority over Its Water Resources; The Law and Policy Governing Alabama Surface Water; The Law and Policy Governing Alabama Groundwater; Water Quality Regulation in Alabama; Instream Flow Science in Alabama; Interbasin Transfers in Alabama; Alabama Public Rights in Water; Alabama Drought Management; Alabama Watershed Management; Special Issues for Water Use by Alabama Municipalities; Special Issues for Water Use by Alabama Irrigators; Water Issues for Non-Hydropower Energy Producers and for Resources Extraction Industries in Alabama; The Apalachicola-Chattahoochee-Flint Dispute; The Alabama-Coosa-Tallapoosa Dispute. These chapters are completed but not yet published.

ANNUAL TECHNICAL REPORT SYNOPSIS

A. PROJECT TITLE: Water Policy and Law in Alabama

B. PRIMARY PI: Heather Elliott, Professor of Law, University of Alabama School of Law

C. OTHER PI(s): William L. Andreen, Edgar L. Clarkson Professor of Law, University of Alabama School of Law

Bennett L. Bearden (Co-PI), Director, Water Policy and Law Institute, University of Alabama

Patrick E. O'Neil (Co-PI), Director, Ecosystems Investigations Program, Geological Survey of Alabama

D. START DATE: March 1, 2014

E. END DATE: February 28, 2015

F. PROJECT OVERVIEW/SUMMARY: Alabama's current water-law regime, because it is primarily a judicially created common-law regime, is nowhere clearly explicated; such explication is necessary to determine its strengths and failings as the state faces growing pressure on its water resources. This project provides a clear explication of Alabama water law and policy, covering the following topics: surface water rights, groundwater rights, irrigation, municipal water uses, instream flows, interbasin transfers, water quality, watershed management, and drought management. A second phase of the project will compare Alabama water resources law to that of its neighboring states, Florida, Georgia, Mississippi, and Tennessee, as well as other states that generally follow riparian doctrine.

G. PROJECT OBJECTIVE(s): The objective of this project is to produce the definitive statement of Alabama water resources law and policy, including a comparison with the water resources law and policy of other states.

H. METHODOLOGIES: The methodology of this project focuses on gathering existing case law and statutory materials governing Alabama water resources law and policy and formulating a definitive statement of the Alabama law.

I. PRINCIPAL FINDINGS/RESULTS: This project has produced a 345 page treatise on Alabama water resources law and policy with the following chapters: Alabama's Water Resources; Alabama's Ownership of and Regulatory Authority over Its Water Resources; The Law and Policy Governing Alabama Surface Water; The Law and Policy Governing Alabama Groundwater; Water Quality Regulation in Alabama; Instream Flow Science in Alabama; Interbasin Transfers in Alabama; Alabama Public Rights in Water; Alabama Drought Management; Alabama Watershed Management; Special Issues for Water Use by Alabama Municipalities; Special Issues for Water Use by Alabama Irrigators; Water Issues for Non-Hydropower Energy Producers and for Resources Extraction Industries in Alabama; The Apalachicola-Chattahoochee-Flint Dispute; The Alabama-Coosa-Tallapoosa Dispute

J. NOTABLE AWARDS AND ACHIEVEMENTS. N/A

K. PUBLICATIONS GENERATED:

Number of Research Publications generated from this research project:	
Publication Category	Number
Articles in Refereed Journals	0
Book Chapters	0*
Theses and Dissertations	0
Water Resources Institute Reports	0
Articles in Conference Proceedings	0
Other Publications	0

* We have an agreement in principle to publish the results of the research as a treatise published by the University of Alabama Press.

L. PRESENTATIONS MADE:

Bennett Bearden, Interbasin Transfers in Alabama, Alabama Water Resources Conference, September 5, 2014

M. STUDENTS SUPPORTED (Complete the following table)

Number of Students Supported, by Degree	
Type	Number of students funded through this research project:
Undergraduate	
Masters	
Ph.D.	1 Ph.D. candidate, 17 J.D. candidates
Post Doc	

Number of Theses and Dissertations Resulting from Student Support:	
Master's Theses	0
Ph.D. Dissertations	0

N. RESEARCH CATEGORIES: (In column 1 mark all that apply)

	Research Category
	Biological Sciences
	Climate and Hydrological Processes
	Engineering
	Ground Water Flow and Transport
X	Social Sciences
	Water Quality
	Other: Explain

O. FOCUS CATEGORIES (mark all that apply with "X" in column 1):

	ACID DEPOSITION	ACD
	AGRICULTURE	AG
	CLIMATOLOGICAL PROCESSES	CP
	CONSERVATION	COV
	DROUGHT	DROU
	ECOLOGY	ECL
	ECONOMICS	ECON
	EDUCATION	EDU
	FLOODS	FL
	GEOMORPHOLOGICAL PROCESSES	GEOMOR
	GEOCHEMICAL PROCESSES	GEOCHE
	GROUNDWATER	GW
	HYDROGEOCHEMISTRY	HYDGEO
	HYDROLOGY	HYDROL
	INVASIVE SPECIES	INV
	IRRIGATION	IG
X	LAW, INSTITUTIONS, & POLICY	LIP
X	MANAGEMENT & PLANNING	M&P
	METHODS	MET
	MODELS	MOD
	NITRATE CONTAMINATION	NC
	NONPOINT POLLUTION	NPP
	NUTRIENTS	NU

	RADIOACTIVE SUBSTANCES	RAD
	RECREATION	REC
	SEDIMENTS	SED
	SOLUTE TRANSPORT	ST
	SURFACE WATER	SW
	TOXIC SUBSTANCES	TS
	TREATMENT	TRT
	WASTEWATER	WW
	WATER QUALITY	WQL
	WATER QUANTITY	WQN
	WATER SUPPLY	WS
	WATER USE	WU
	WETLANDS	WL

P. DESCRIPTORS: Water Law (268), Water Rights (278), Law (140), Policy Analysis (180), Planning (175), Resource Planning (199), Institutional Relationships (124)

Information Transfer Program Introduction

The Auburn University Water Resources Center facilitates a large statewide conference every September, and the PIs of WRRI-funded projects are required to present their research finding at this conference. The Center also sponsors several other smaller symposia, and other outreach and technology transfer activities, and maintains a website containing numerous resources and information/result reports from WRRI-funded projects. However, no WRRI 104 funds or matching funds are used to support any of the technology transfer activities.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	4	0	0	4
Masters	1	1	0	0	2
Ph.D.	18	0	0	0	18
Post-Doc.	0	0	0	0	0
Total	19	5	0	0	24

Notable Awards and Achievements

The PIs for the currently funded 104b and 104g research projects did not report any "notable achievements and awards."