



Savannah River Ecology Laboratory
Annual Technical Progress Report
2003

SAVANNAH RIVER ECOLOGY LABORATORY

ANNUAL TECHNICAL PROGRESS REPORT OF ECOLOGICAL RESEARCH

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THE SAVANNAH RIVER ECOLOGY LABORATORY

OVERVIEW

Origin

The Savannah River Ecology Laboratory (SREL) was founded in 1951 by Dr. Eugene P. Odum of The University of Georgia, who began ecological baseline studies on the Savannah River Site with financial support from the Atomic Energy Commission. Throughout its history, SREL has been operated by The University of Georgia.

Mission

The Savannah River Ecology Laboratory's mission, as defined in its Cooperative Agreement with the U.S. Department of Energy (DOE), is to provide an independent evaluation of the ecological effects of Savannah River Site (SRS) operations through a program of ecological research, education, and outreach. This program involves both basic and applied environmental research, with an emphasis upon expanding the understanding of ecological processes and principles, particularly as they relate to environmental remediation sciences.

This mission is accomplished through a broad-based program of field and laboratory research conducted on the SRS and published in the peer-reviewed scientific literature; by providing education and research training for undergraduate and graduate students from colleges and universities throughout the United States and abroad; and by engaging in community outreach activities and service to professional organizations.

Funding

The Savannah River Ecology Laboratory's primary funding source is a Cooperative Agreement between the U.S. Department of Energy and The University of Georgia Research Foundation that covers a five-year period from July 1, 2001 through June 30, 2006. The estimated total cost of this agreement is almost \$53 million, with DOE contributing about \$50 million and the University of Georgia about \$3 million. Additional funding, about \$1.0 million in FY03, comes from other contracts and grants involving a variety of other organizations. SREL's total operating budgets from DOE and other federal sources in FY00, FY01, FY02, and FY03 were \$8.9, \$9.7, \$10.2, and \$10.2 million, respectively. In FY03 SREL received about \$7.3M from DOE Office of Science (DOE-SC); the FY04 budget from DOE-SC is projected to be \$8.0 million. SREL also receives almost \$550,000 per year from The University of Georgia. During FY03 an additional \$1.4M was received from DOE and WSRC for SRS-related tasks and outreach.

Staffing

The Savannah River Ecology Laboratory currently has a staff of about 190 people, nearly all of whom are employees of The University of Georgia. The staff includes 20 faculty, six of whom are co-staffed through tenure-track positions in various departments at The University of Georgia and one who is co-staffed through a tenure-track position in the School of Public Health of the University of South Carolina. There are another 14 Ph.D.s in other technical positions or postdoctoral appointments. Research technicians (87), clerical and other support personnel (48), and graduate students (22) comprise the remaining staff categories.

Organizational Structure

The Savannah River Ecology Laboratory is a research unit of The University of Georgia and its Director reports to the UGA Vice President for Research. At DOE-HQ, SREL and its Director report to the Director of the Environmental Remediation Sciences Division within the Office of Biological and Environmental Research, Office of Science. At the Savannah River Site, SREL and its Director report to the DOE Assistant Manager for Environmental Programs, Science and Technology. Internally, SREL is organized into four research groups, an environmental outreach program, and support services.

Facilities

The Savannah River Ecology Laboratory's main facility consists of a 45,000-ft² building with offices, general and specialized laboratories (e.g., molecular, GIS, analytical instrumentation), meeting rooms, a computer center, and a library. Additional buildings and research facilities surround the main lab, including a distance learning facility, greenhouse complex, rhizotron/lysimeter, animal holding buildings, and a maintenance shop. A 5,000-ft² laboratory and additional offices are located in B-Area, about 5 miles from the main lab, and a 3,500-ft² radioecology laboratory is located at Par Pond, about 15 miles from the main lab. A 5,000-ft² conference center was built by The University of Georgia on SRS land leased to the University.

Additional information about SREL can be found on the laboratory's Internet web site: <http://www.uga.edu/srel/>

SAVANNAH RIVER ECOLOGY LABORATORY

MISSION FOCUS

Safety and Security

- DOE approval of the Necessary and Sufficient process to ensure the safety and health of SREL employees by adopting work-smart safety and environmental standards.
- ISO 14001 certified.

Technical Capability

- Publication of 77 journal articles, with an additional 77 articles submitted or in press.
- Funding from 39 grants totaling about \$1M in FY03.
- Faculty positions in 11 University of Georgia departments and adjunct faculty positions at 21 other universities and research institutions.
- Service on over 60 editorial boards/committees.
- Presentation of more than 100 scientific presentations and lectures.
- 19 undergraduate and 40 graduate students conducting research.
- SREL students were awarded 3 masters and 4 doctorate degrees in FY03.
- In the last year, SREL sponsored three co-op students from local universities in its Computer Services Group.
- SREL personnel include 32 Ph.D. level scientists with 87 supporting technicians.
- The Laboratory continues to maintain state-of-the-art analytical capabilities.
- An automated vadose monitoring and pore water sampling system was designed, constructed, and used to monitor tritium migration through the vadose zone at the Mixed Waste Management Facility's phytoremediation site.
- A new photon correlation spectrometer/laser doppler velocimeter was purchased and installed for evaluating changes in particle size and surface charge (i.e., zero point of charge) of dilute suspensions in response to alterations in the chemical environment.
- Analytical methodology was developed to apply laser ablation ICP-MS to the direct analysis of small solid samples of animal tissue to assess prior contamination exposure. The technique allows sampling tissues such as hair, feathers, and tail and toenail clips without the need to sacrifice the individual.
- Consistent with solubility information gained from chemical extraction techniques, the addition of phosphorus in the form of hydroxyl apatite has been demonstrated to reduce the bioavailability/toxicity of Ni to sulfate reducing bacteria (SRB), a TCE degrading bacteria, nematodes, and earthworms.
- Synchrotron-based X-ray microanalysis of thin sections prepared from aged contaminated soil and sediments from the Tims Branch/Steed Pond system reveal different mechanisms and rates of sequestration of the co-contaminants U and Ni during long term aging
- Studies using earthworms as bioreceptors in laboratory exposure demonstrate significant U and Ni accumulation upon exposure to Steed Pond and Tims Branch sediments and that bioaccumulation is related the chemical speciation rather than total concentration.
- Isotope ratio mass spectrometry (C- and N-stable isotopes) was used to determine the trophic pathways of contaminant uptake and the co-association of contaminants (e.g., Se and Hg) in biological tissues of invertebrate and vertebrate species on the SRS and elsewhere.
- Preliminary hydroacoustic surveys were conducted on PAR Pond, L Lake, and Pond B. Multiple transducers were used to provide information about bathymetric topology (e.g., depth, distance from bank, and slope), lake-bottom sediment class types, and abundance of submerged aquatic vegetation.
- Research continued on developing the best methods for relocating and establishing viable populations of the gopher tortoise, a species listed as federally threatened in several SE states.
- The effects of a heavily used pesticide, carbaryl, on the aquatic life stage of two common salamander species (marbled

and spotted salamanders) were examined. Increased concentrations of the pesticide resulted in lower survivorship, reduced growth and lipid content, and increased the time to metamorphosis of both species.

- Optically stimulated luminescence (OSL) has made it possible to date the formation of inland dunes and sand rims of Carolina bays on the southern Atlantic Coastal Plain. The ages for bays, including Flamingo Bay and Bay 40 on the SRS, indicate episodes of moister climate around 110,000, 80,000 and 40,000 years before present.
- Crayfish exposed to environmentally realistic mercury concentrations accumulate this metal, and may serve as a vector carrying mercury into terrestrial food webs.
- Laser ablation-ICPMS techniques were developed for use as a nondestructive indicator of contaminant exposure. LA-ICPMS can be a powerful tool for predicting an organisms previous exposure to As and Se.
- Studies found that trophic and maternal transfer are significant routes of Se mobility in high trophic level predators such as snakes and birds. Depending on the concentrations of Se ingested, offspring viability of affected females is at risk.
- Addition of illite minerals to ¹³⁷Cs-contaminated wetlands bind ¹³⁷Cs and make it less bioavailable, yet do not destroy the sensitive wetland, as do traditional remediation methods. The technique has been very successful, reducing ¹³⁷Cs concentrations in water some 40-fold, with 2- to 3-fold reductions in plants and fish.
- Whole transcriptome gene chips were used to identify candidate genes in Arabidopsis plants that respond to specific contaminants.

Community, State, and Regulator Relationships

- Using grant funds, the SREL Outreach Program initiated a new hands-on “research-to-classroom” science program at two “at-risk” elementary schools in Aiken County. Every 4th and 5th grade student at each school participated in five two-hour science workshops and a daylong field trip that stressed science inquiry and process skills and highlighted SREL researchers.
- The Outreach Program reached the general public through more than 416 events in an attempt to improve scientific literacy.
- Several SREL researchers and staff members are working with city and county planning personnel to develop a plan for the future of the Upper Three Runs Creek watershed. Upper Three Runs Creek has been the site of many SREL research studies.
- SREL personnel continue to interact with SRS, SCDHEC, and EPA personnel in the Integrated Operable Unit program within Westinghouse Savannah River Company Environmental Restoration Division.

Cost Effectiveness

- SREL's overhead rate is among the lowest in the DOE complex.
- SREL continues to replace General Services Administration vehicles with lower cost University of Georgia vehicles.
- UGA returns nearly \$550,000 to DOE as faculty salaries, new vehicles, foreign travel, and capital equipment. This amount is nearly equal to SREL indirect charges.
- UGA operates SREL on a nonprofit basis.

A Corporate Perspective

- SREL participates in joint research proposals and projects with National Laboratories, other DOE sites, and universities.
- SREL faculty and staff participate in national DOE review committees (WIPP, EMSP, SERDP).
- The Distance Learning Facility provided nearly 300 hours of academic and non-academic programming to SRS personnel. The Distance Learning Program offers a graduate degree in Environmental Toxicology from The University of Georgia.
- SREL personnel continue to participate in the site-wide environmental committees and the U.S. Forest Service-SR ID team.

SUMMARY

The Savannah River Ecology Laboratory (SREL) is a research unit of The University of Georgia (UGA) and has been conducting ecological research on the Savannah River Site (SRS) near Aiken, South Carolina for over 52 years. The overall mission of the Laboratory is to acquire and communicate knowledge of ecological processes and principles. SREL conducts fundamental and applied ecological research, as well as education and outreach programs, under a Cooperative Agreement with the U.S. Department of Energy (DOE).

The Laboratory's research mission during the 2003 fiscal year was fulfilled with the publication of 77 journal articles and book chapters by faculty, technical staff, students, and visiting scientists. An additional 77 journal articles have been submitted or are in press. Other noteworthy events took place as faculty members, staff, and graduate students received awards. These are described in the section titled Special Accomplishments of Faculty, Staff, Students, and Administration on page 46.

Notable scientific accomplishments include work conducted on microbially mediated geologic processes, studies of the ecological effects of large-scale disturbance, and innovative methods to remediate soils and wetlands contaminated with heavy metals and radionuclides.

- Drs. Chuanlun Zhang and Christopher Romanek were guest editors of a special issue of *Chemical Geology* published in April 2003. The special issue, Isotopic Records of Microbially Mediated Processes, contains an overview and thirteen scientific articles.
- Dr. Rebecca Sharitz and others received a multi-year grant from the Strategic Environmental Research and Development Program (SERDP) to evaluate effects of military training and land management activities on sandhill communities and rare species.
- Dr. Domy Adriano was a co-recipient of Austrian patent A1525/2000 for an invention that uses the combination of a plant and a chemically reactive mat to remove contaminants, such as heavy metals and radionuclides, from soils. When the plant takes up contaminants from the soil, they may be transferred to the leaves, which ultimately fall to the ground. On the ground is a chemically reactive mat, which binds the contaminants in place when the leaves decay. After a period of time, the mat is removed for disposal.
- Dr. Tom Hinton and others completed field deployment of an *in situ* remediation method for ¹³⁷Cs-contaminated wetlands. The method, which involves the application of illite clay to contaminated wetlands, appears to be very successful in binding cesium in place.

SREL's research was enhanced this year by the addition of two new faculty members in late summer 2002. Drs. Chuanlun Zhang, who specializes in geomicrobiology and environmental microbiology, and Andrew Neal, who studies metal metabolism by bacteria, both joined SREL's AACES research group. The addition of these faculty members and their research programs prompted SREL and the Savannah River Technology Center to draft a cooperative agreement that is intended to foster collaboration among the environmental microbiology researchers from the two laboratories while leveraging expertise and facilities to address environmental issues on the SRS and across the DOE complex. As a result of this agreement, Drs. Zhang and Neal will share research space at the SRTC Environmental Biotechnology Laboratory located in the Aiken County Technology Center; SREL research facilities and instrumentation will also be available to SRTC researchers. This initiative should make it easier for both groups to collaborate on joint research proposals and to work together on cooperative research projects.

With passage of the FY03 federal budget, programmatic authority for SREL officially changed from local DOE-SR to the DOE

Office of Science (DOE-SC). SREL is now an important component of the new Environmental Remediation Sciences Division (ERSD) within the DOE-SC Office of Biological and Environmental Research. Much of the past year has been spent working out the logistics of SREL's transition to the Office of Science. A DOE-SC review of SREL research programs is planned for early FY04 and SREL researchers are evaluating current laboratory research programs in light of the new ERSD mission.

During spring 2003 SREL underwent a Program Review by the UGA Program Review and Assessment Committee and the Office of the Vice President for Instruction. The purpose of the review was to provide a systematic means of assuring the continuous improvement of the University's academic, research, and service programs. To begin the review process, in December 2002 SREL submitted a Self Study, which was intended to provide a mechanism for the laboratory to undertake a thorough self-evaluation of program goals and successes. In May 2003 a four-member UGA assessment team spent two days at SREL, meeting with all groups within the Lab. All personnel were also asked to respond to an on-line survey that contained questions specific to each personnel group. The assessment team is expected to submit a draft of their review report by the end of FY03.

Two longtime SREL faculty members retired during FY03. Dr. Justin Congdon retired at the beginning of July, 2002, and Dr. Michael Smith retired at the end of December. Dr. Congdon, who was appointed as Emeritus Professor at UGA, continues to collaborate on SRS research projects and remains active with turtle research in Michigan, although he has moved his home to Arizona. Dr. Smith also continues to work on projects with SREL researchers while collaborating with colleagues at the Illinois State Museum.

Researchers at SREL currently have funding totaling about \$1M from 39 grants in addition to funds provided by DOE-SR. Sources of grant awards range from private foundations such as The Christensen Fund to federal agencies such as the U.S. Environmental Protection Agency, the National Science Foundation, and the Department of Defense (DoD). Important grants received this year included an award of \$478,000 over three years to Dr. Paul Bertsch from the Department of Energy Office of Science to study chemical speciation and bioavailability of uranium and nickel in contaminated sediments, \$80,000 for one year to the SREL Outreach Program from The Christensen Fund for a hands-on "research-to-classroom" science program for elementary schools, and \$358,341 over three years to Dr. Chuanlun Zhang from the National Science Foundation to study biogeochemical processes in gas hydrate systems in the Gulf of Mexico. An additional \$1.4M was received from DOE and WSRC for SRS-related research and outreach activities.

During FY03 SREL purchased about \$450,000 worth of major equipment items from its equipment budget. About \$150,000 of this amount came from The University of Georgia, and the remainder from DOE. In addition to replacing some existing equipment and general use items, funds were used to purchase start-up equipment for new faculty and to upgrade an existing mass spectrometer.

Participants in the SREL Education Program during FY03 came from schools located throughout the United States and included 19 undergraduate students and 40 graduate students. The graduate students came from six different universities in the U.S. and abroad, emphasizing the national and international stature of the SREL program. In the past year three graduate students from SREL earned Masters Degrees and four earned Doctor of Philosophy Degrees. A National Science Foundation grant from the Research Experiences for Undergraduates Program for a proposal titled "The Impact of Energy Technologies on Natural Environmental Systems" continued to provide funding for the undergraduate program at SREL.

In addition to holding faculty positions in 11 departments at the University of Georgia, various SREL faculty have adjunct status at 21 other colleges and universities. Faculty, staff, and students also are active in providing outreach and service to the scientific community. Representatives from the laboratory hold more than 60 editorial or committee positions in national groups and organizations and also serve on several UGA academic and administrative committees. Over 100 lectures, scientific presentations, and posters were presented during the past year at scientific meetings, colleges, and universities, including minority institutions.

The SREL Outreach Program reaches a different audience in its efforts to communicate scientific awareness to the general public. During the past year, SREL scheduled 329 talks, 9 tours, 29 exhibits, and 49 workshops, for a total of 119,400 people reached. Topics of these presentations included biodiversity, the process of science, animal adaptations, plants and wetlands, environmental science and chemistry, local ecosystems and conservation, classification, and careers in ecology and research. A book produced by the SREL Outreach Program, *The Snakes of Georgia and South Carolina*, originally released to the public in May 1998, has been so well received that a fourth printing was done in 2002. Other educational products produced during the past year included a 6-page full color flier on the American alligator, a pamphlet on the eastern indigo snake, a large poster in support of amphibians, reptiles, and their habitats, and an emergency services calendar that depicts animals, plants, and habitats of the SRS, produced in cooperation with Westinghouse Savannah River Company. All of these new materials and other Outreach products have been extremely popular and thousands of copies have been distributed during the past year.

The SREL Distance Learning Program continued to focus its efforts on programming related to the Laboratory's core programs in ecology and environmental science. SREL, in cooperation with and with funding from the UGA College of Pharmacy, is offering a multidisciplinary Master's Degree in Environmental Toxicology via the Georgia Statewide Academic and Medical Systems (GSAMS) network. This is the first degree offered by UGA through any distance learning site in Georgia or South Carolina. Three students are continuing into the second year of coursework for the degree. Six students have completed all required coursework and are working on the research component of the degree and one student has graduated from the program. In an effort to expand their audience, the SREL Outreach Program presented 18 Ecotalks via distance learning to elementary, middle, and high school students in both South Carolina and Georgia. This approach allows Outreach staff to reduce animal handling and transport time and reach multiple schools simultaneously.

The Conference Center has continued to see wide use, both by SREL personnel and the local community. The facility was used to host a total of 90 scientific meetings and environmental education programs for students, teachers, and the general public this past year, and 3,162 people visited the facility. Funding is being sought to construct a Nature Center for outreach activities at the Conference Center site.

Representatives of the Laboratory also serve local and statewide communities by organizing a canned goods drive in November, managing a recycling program, participating generously in the UGA Campaign for Charities, hosting an annual auction benefiting the South Carolina Chapter of The Nature Conservancy, and participating in the regional Heart Walk to benefit the American Heart Association.

AN OVERVIEW OF RESEARCH PROGRAMS AND PROGRAM COMPONENTS

Research at the Savannah River Ecology Laboratory is conducted within the framework of four research groups. While research is conducted within this framework, it is not restricted by it. Multidisciplinary and multi-investigator driven research projects are encouraged. More detailed information about each research group and its individual projects follows.

The four research groups are:

- Advanced Analytical Center for Environmental Sciences (AACES)*
- Ecological Stewardship*
- Ecotoxicology, Remediation, and Risk Assessment (ETRR)*
- Radioecology*

ADVANCED ANALYTICAL CENTER FOR ENVIRONMENTAL SCIENCES (AACES)

Advanced analytical and spectroscopic techniques provide an opportunity to generate new scientific knowledge needed for solving complex environmental problems, as well as developing cost-effective remediation strategies. Application of these advanced methods can provide scientifically defensible data to support risk assessment-based remediation strategies that involve in situ stabilization or monitored natural attenuation, both of which should significantly reduce costs. Included in the diverse array of advanced instrumentation being applied to analyze complex environmental samples and elucidate fundamental processes are: synchrotron X-ray absorption spectroscopy, ion cyclotron resonance mass spectrometry, isotope ratio mass spectrometry, inductively coupled plasma mass spectrometry and optical emission spectroscopy, atomic force microscopy, FT-Raman and FT-IR spectroscopies, X-ray diffraction and solid-state tunable laser spectroscopy.

AACES is organized around four interactive research programs in:

- Analytical Applications and Technology Development for the Characterization of Complex Wasteforms and Environmental Samples*
- Environmental Chemistry and Transport of Contaminants through Ecosystems*
- Environmental Remediation and Waste Minimization*
- Molecular Microbiology and Biogeochemistry for Environmental Remediation Research*

AACES objectives are to:

- Serve as an advanced research and development facility with a primary interest in bridging basic and applied environmental research from the molecular to landscape level;*
- Acquire and develop the infrastructure to provide local, regional and national users from industry, government, and universities with both the expertise and advanced methods required to generate a better understanding of contaminant behavior in the environment, elucidate molecular mechanisms of toxicity, and develop better, cheaper and more environmentally sound remediation approaches; and*
- Provide a mechanism for the further development, modification, and application of advanced analytical and spectroscopic techniques to better understand complex environmental processes.*

Analytical Applications and Technology Development for the Characterization of Complex Wasteforms and Environmental Samples

Principal Investigators: Paul M. Bertsch, Brian P. Jackson, Gary L. Mills, Andrew Neal, Christopher S. Romanek, and John C. Seaman

The remediation and restoration of contaminated sites throughout the U.S. Department of Energy (DOE) weapons complex present formidable problems due to the diversity and complexity of both the waste mixtures and subsurface environmental matrices. Scientifically sound characterization, remediation, and performance assessment technologies that are cost-effective and provide acceptable risks to humans and ecosystems are needed to achieve regulatory objectives and to fulfill DOE's waste management and cleanup goals. The successful development and implementation of these technologies require knowledge of the chemical speciation, spatial distribution, reactivity, transformation reactions, geochemical mobility, and bioavailability of contaminants at the atomic and molecular scales that can be used to interpret and predict contaminant behavior at microscopic, macroscopic, and field scales. The various research programs within the Advanced Analytical Center for Environmental Sciences (AACES) address these issues by employing an integrated, multidisciplinary, multiscale approach to studies at the interface between basic and applied environmental research. The Analytical Applications and Technology Development Program, which focuses on the development and application of advanced analytical techniques for the molecular scale characterization of complex wasteforms and environmental samples, is a cornerstone component of the research efforts within AACES. Using an array of "state-of-the-science" analytical instruments and technologies, the program develops and applies novel and innovative methods to acquire the molecular scale measurements that are prerequisite to conducting studies within this program and other programs at SREL.

- An automated vadose monitoring and pore water sampling system was designed and constructed in collaboration with researchers and engineers from Clark Atlanta University (Dr. S. Aburime) and Dynamax Inc. (M. van Bavel). The prototype system was used to monitor tritium migration through the vadose zone at the Mixed Waste Management Facility's phytoremediation site. Development of remote control telemetry capability and optimization of the system is ongoing.
- A new photon correlation spectrometer/laser doppler velocimeter (Zetasizer 3000HS; Malvern Inc.) was purchased and installed for evaluating changes in particle size and surface charge (i.e., zero point of charge) of dilute suspensions in response to alterations in the chemical environment.
- Laser-based spectroscopic capabilities are being upgraded, including over-haul of FT-Raman and FT-IR benches as well as purchase of a new Raman microscope system. The MOPO laser system is also being brought back up to a fully operational status.
- High resolution gas chromatography and gas chromatography-mass spectrometry was used to determine the oxidative metabolites of volatile chlorinated hydrocarbons in exposed vegetation.
- A variable ratio flow splitter was acquired for the electrospray ionization (ESI) source used with liquid chromatograph-Fourier transform ion cyclotron resonance mass spectrometer (LC-FT-ICR-MS). The variable flow splitter allows optimization of the low flow rate necessary to maximize ionization and consequently, ion-abundance in the FT-ICR-MS detection cell.
- Commissioning of micro-XAFS and micro-diffraction techniques at the hard X-ray micro-probe, X26A, at the National Synchrotron Light Source at Brookhaven National Laboratory commenced this past year. These techniques are being coupled with micro-XRF analyses to provide detailed information on the distribution and chemical speciation of radionuclides, metals, and metalloids in soils, biota, and wasteforms. The installation and commissioning of a new liquid cooled Si (111) monochromator crystal (and tank) greatly enhanced the optics of the beamline with an enhanced flux, energy range (4.8-22 KeV), and outstanding energy resolution improvement. A liquid cooled Si (311) crystal is scheduled to be installed and commissioned in the winter shutdown. This addition will greatly improve energy resolution for XAFS and extend the energy range up to about 40 KeV. The Canberra 13 element Ge array detector was completed and installed this past winter/spring and is in the processes of commissioning. New miniaturized Io and It chambers have been constructed and commissioned and these will greatly facilitate micro-EXAFS investigations.
- Analytical methodology was developed to apply laser

ablation ICP-MS to the direct analysis of small solid samples of animal tissue to assess prior contamination exposure. The technique allows sampling tissues such as hair, feathers, and tail and toenail clips without the need to sacrifice the individual. The technique showed promise for long-term exposure and uptake studies.

- An existing isotope ratio mass spectrometer (IRMS) was upgraded to perform compound specific isotope ratio analysis. The upgrade included a GC and GC-C-combustion interface for the introduction of purified compounds into the source of the IRMS. The expanded capabilities include the analysis of hydrogen, carbon, oxygen and nitrogen stable isotopes from purified and derivatized compounds. Target materials to be analyzed in the near future will include bacterial and archeal lipids, and amino acids from protein extracts of biological tissues.
- Laser-ablation ICP-MS, FT-Raman and FT-IR instrumentation were used to characterize the inorganic and organic components of biomineralized tissues (shells of freshwater bivalves) collected from polluted environments on the SRS. Samples were also analyzed for their carbon and oxygen stable isotope composition using the IRMS. The isotope records will be used as a chronometer to decipher the historical records of contaminant exposure locked in the shells of the bivalves.

Environmental Remediation and Waste Minimization

Principal Investigators: Domy C. Adriano, Paul M. Bertsch, Gary L. Mills, Andrew Neal, Christopher S. Romanek, John C. Seaman, and Brian P. Jackson

The operation of the DOE weapons complex over the past 40+ years has resulted in a diverse array of environmental problems that involve the chemical contamination of surficial and subsurface materials. These contaminants include both stable elements and radionuclides in a variety of inorganic and organic compounds, including reactive metals (e.g., Ni, Al, Cr, Cu, Cd, Zn, As, U, Cs), organometallic compounds (e.g., organo-Hg and -Se species), and organic chemicals (e.g., Light and Dense Non Aqueous Phase Liquids, halogenated hydrocarbons, fuel additives, polychlorinated biphenyls and polycyclic aromatic hydrocarbons). In addition, coal combustion residues (e.g., fly ash, flue gas desulfurization sludge) from electrical power facilities

constitute a major source of solid waste at many DOE and commercial sites. Such contaminants can be found together in complex associations of mixed waste and pose significant human health and ecological risks.

These contaminants must be removed from the environment or transformed into benign substances through active or passive remediation efforts. Scientists participating in the Environmental Remediation and Waste Minimization Program at SREL focus interdisciplinary research efforts on the characterization of the source, state, and fate of environmental contaminants, the identification of processes and mechanisms of remediation, and the development of methods for waste minimization that reduce the cost of the cleanup at contaminated sites on the SRS and throughout the DOE complex.

- The Unsaturated Flow Apparatus (UFA) was used to evaluate the land application of coal combustion fly ash as a means of increasing the water holding capacity for coarse-textured agricultural soils. Application rates in excess of 5% by weight were required to see a significant increase in water holding capacity, as lower application rates actually reduce the water holding capacity by increasing the pore solution ionic strength, resulting in a well-flocculated clay fraction compared to the control soil.
- *In situ* redox manipulation (ISRM) is one type of permeable reactive barrier used to treat contaminated groundwater. Our studies have evaluated the use of ISRM technology for remediation of SRS ground water contaminated with organic and metal contaminants. Using laboratory column experiments we have previously demonstrated that dithionite-reduced aquifer sediments completely removed Cr (VI) but only 40-60% of TCE and PCE in groundwater. Current studies have shown that ISRM applied to these sediments was effective in completely removing carbon tetrachloride, indicating that this technology may be successfully deployed for the treatment of highly oxidized chlorinated hydrocarbons when a sufficient redox potential can be established.
- Consistent with solubility information gained from chemical extraction techniques, the addition of phosphorus in the form of hydroxyl apatite has been demonstrated to reduce the bioavailability/toxicity of Ni to sulfate reducing bacteria (SRB), a TCE degrading bacteria, nematodes, and earthworms. These studies

demonstrate that moderate additions of hydroxyl apatite can be used as an *in situ* remediation strategy, greatly reducing or eliminating ecological risk.

- Existing information on the distribution of metals (e.g., As, Cd, Cr, Fe, Al, Hg, Pb, and Zn) in surface soils of the SRS was collected and incorporated in a statistical model to determine percentile rankings for analytes having a large proportion of detects. A spatial declustering routine was developed to weight sampling sites that distributed in a non-random pattern across a landscape. A GIS coverage was then developed to predict the metal concentration of soils at various scales across the landscape. The coverage provides a geospatial representation of potential source terms that can be used to study contaminant uptake and transfer in natural and impacted ecosystems.
- A treatability study, in cooperation with the USFS-SR (Forest Service) and ER (Environmental Restoration) was re-established in February 2001 in the 488 D-Area ash basin. This work involves the use of a vegetative cover (as a solar-driven pump) and non-invasive chemical treatments, using common and inexpensive ameliorants to mitigate the high acidity and salinity resulting from the oxidation of pyrite in the coal refuse particles. The major amendments included the use of topsoil, coal fly ash (on site), and biosolid compost to provide a more ecologically friendly growth substrate for inoculated one-year-old pine seedlings. Seedlings planted on the new plots that were not ripped previously (deep disking to ~3') had very high mortality rate, apparently due to dense soil structure that roots cannot easily penetrate. Seedlings grew much better on plots amended with either the topsoil, fly ash, apatite, or biosolid. Most recent observations indicate that plant roots are developing well, penetrating deeper than the treatment zone. These field results were corroborated by results from the SREL cattle tank farm using the same coal refuse medium and amendments.
- Sequential chemical extraction of metal-contaminated soils can be used to evaluate the potential efficacy of soil remediation techniques where certain soil amendments were used for *in situ* stabilization. It can also serve as an indicator of natural attenuation, herein called natural remediation. In addition to modifying partition coefficients that include a bioavailable component, other indices, which include less labile contaminants, are proposed. These indices may have some potential in the risk assessment of high metal-contaminated soils. This

technique has been compared with other bioavailability assays, including biological and physiological tests as a potential tool in risk assessment. Recently, this technique is being tested to help elucidate key rhizosphere processes in contaminated and treated soils.

Environmental Chemistry and Transport of Contaminants through Ecosystems

Principal Investigators: Paul M. Bertsch, Gary L. Mills, Andrew Neal, Christopher S. Romanek, and John C. Seaman

The legacy of nuclear materials production and processing for the manufacture of nuclear weapons has resulted in significant quantities of contaminant metals, such as uranium, nickel, chromium, and copper, and lesser quantities of a number of longer lived radionuclides (i.e., ⁹⁰Sr and ¹³⁷Cs) and transuranics, as well as a wide range of contaminant organics, being introduced into soils and sediments throughout the U.S. DOE complex. Chemical speciation and/or contaminant mineral-surface interactions are the primary parameters controlling transport, bioavailability, and toxicity of metals, metalloids, and radionuclides from waste forms and within the environment. The subsurface migration of contaminants and contaminant mixtures within complex heterogeneous geologic systems is also controlled by various reactive mineral and organic components.

A more complete understanding of chemical species distributions and transformations and of the importance of physicochemical, mineralogical, and biogeochemical controls is required to accurately predict contaminant migration, to evaluate environmental risk, and to design cost effective yet environmentally sound remediation strategies.

This research effort is designed to: (1) determine the chemical speciation of metals, metalloids, radionuclides, and contaminant organics in a range of waste forms and SRS environs by standard and novel wet chemical and advanced techniques; (2) evaluate the biogeochemical dynamics of these contaminants as influenced by natural processes and various chemical and biological remediation strategies; (3) perform detailed physicochemical characterization of the Coastal Plain soils and aquifer sediments on the SRS and identify critical mineral surface/contaminant interactions; (4) determine static contaminant partitioning/extraction as a

function of local solution conditions (i.e., groundwater chemistry, contamination events, etc.) and soil/aquifer mineralogy; and (5) conduct intermediate/field-scale dynamic transport studies, which are analogous to the kinetically controlled conditions experienced in the field, to identify the mechanisms controlling the natural attenuation of contaminants and the impact of various proposed remediation/reclamation strategies.

- An extensive series of unsaturated column experiments were conducted to compare solute migration behavior observed for the centrifuge-based Unsaturated Flow Apparatus (UFA) compared to the more common vacuum-based column systems. Based on tritium migration, hydrodynamic dispersion increased with decreasing water content, and Cr(VI) partitioning, as indicated by the K_d , showed little response to water content for both systems, despite extreme differences in solute residence time, indicating that sorption kinetics played a minor role in transport.
- HYDRUS-2D, a numerical model developed by researchers at the USDA for simulating one and two-dimensional variably saturated solute transport in the vadose zone, was used to describe tritium migration at the MWMF as a means of characterizing the physical aspects of solute transport.
- Indigenous rodents were captured at the Mixed Waste Management Facility's phytoremediation site in an effort to determine tritium burdens within wildlife receptors currently residing within the irrigation area. In addition, blood samples were collected from select individuals for DNA strand breakage analysis as an indicator of deleterious contaminant exposure. Tritium concentrations in the captured animals ranged from <9 to 3204 pCi/mL of body fluid, significantly less than the applied tritium levels in the irrigation water, approximately 10,000 to 15,000 pCi/mL.
- Comparative studies have been performed on Zn sorption to the iron-oxide Goethite and natural sediments in the presence and absence of the iron-reducing bacterium *Shewanella putrefaciens* demonstrating significant differences not only due to the presence of bacteria but also due to the contrasting chemistries of the two sediment systems. This work demonstrates that bioremediative strategies based upon synthetic iron-oxide experimentation does not reflect the complexity encountered in natural sediment systems.
- Synchrotron-based X-ray microanalysis of thin sections prepared from aged contaminated soil and sediments from the Tims Branch/Steed Pond system reveal different mechanisms and rates of sequestration of the co-contaminants U and Ni during long term aging. Fe-oxide mineral phases are critical mechanisms controlling natural attenuation processes of Ni in sediment strata low, medium, and high in organic matter (~1 to 14%), whereas U is typically partitioned to detritus and organic rich regions that are spatially separated from regions of Ni accumulation. More detailed work in the past year has also lead to the hypothesis that U partitioning to organics evolves during the degradation/humification process. Whereas U is excluded from live roots, U becomes more commonly associated with aged organic features. Ni displays the opposite trend, being commonly associated with live roots but generally not associated with highly aged organic features. Correlations generated from elemental distribution maps demonstrate that Ca is a good indicator of organic rich features, whereas Ti is a very good signature of Fe-oxide rich, organic poor regions.
- Collaborative studies with researchers from the Medical University of South Carolina have demonstrated that Ni in the Steed Pond system is toxic to a variety of microorganisms, including sulfate reducing bacteria and those responsible for degrading TCE. The studies have also revealed that a genetically modified metal tolerant TCE degrader (*Burkholderia cepacia* PR1301) demonstrates greater resistance to Ni at pH 5 rather than pH 6 or 7. Similar toxicity trends with pH have been demonstrated for indigenous microorganisms isolated from the Steed Pond system. Studies with carefully selected growth media demonstrate that the observed toxicity is counter to predictions based on the free ion activity model. Recent proteomics studies have also demonstrated the expression of specific proteins related to Ni exposure at pH 5 that are minimally expressed at pH 6 and not expressed at pH 7. The 2-D gels are to be analyzed by FT-MS to identify the proteins.
- Studies using earthworms as bioreceptors in laboratory exposure demonstrate significant U and Ni accumulation upon exposure to Steed Pond and Tims Branch sediments and that bioaccumulation is related the chemical speciation rather than total concentration. Addition of humic material to contaminated soils also greatly enhanced U bioavailability. Earthworms collected

from contaminated soils along the Tims Branch corridor were also enriched with U and Ni. SEM/EDX studies are currently underway to determine the nature of the U within the earthworm tissues.

- Two separation techniques (field flow fractionation [FFF] and size exclusion chromatography [SEC]) coupled to ICP-MS have been used to provide information on the chemical speciation of U and Ni complexes in pore waters from different contaminated regions along the Tims Branch corridor. Preliminary analyses indicate that aqueous phase U collected from pore waters is present primarily as a high molecular weight colloidal fraction along with humic bound and lower molecular weight complexes. Ni is primarily present as the free ion and as a low molecular weight complex, with the relative distribution between these two forms being variable depending on sampling location.
- An evaluation of techniques for determining frayed edge sites (FES) on micaceous minerals and their weathering products revealed discrepancies that could be explained based on differences in Cs, K, and NH_4 exchange preference. A refined method was developed and applied to soils from the INEEL and the SRS to quantify FES capacities.
- Isotope ratio mass spectrometry (C- and N-stable isotopes) was used to determine the trophic pathways of contaminant uptake and the co-association of contaminants in biological tissues of invertebrate and vertebrate species on the SRS and elsewhere. It was determined that the ratio of the nitrogen isotope composition of liver and muscle provides a more sensitive indicator of environmental stress than conventional biomarkers such as the metal defensive peptides, metallothionein and glutathione.
- Isotope ratio mass spectrometry (C- and N-stable isotopes) was used to determine the trophic pathways of contaminant uptake and the co-association of contaminants (e.g., Se and Hg) in biological tissues of invertebrate and vertebrate species on the SRS and elsewhere.

Molecular Microbiology and Biogeochemistry for Environmental Remediation Research

Principal Investigators: Chuanlun L. Zhang, Andrew Neal, Christopher S. Romanek, Gary Mills, Paul Bertsch, Domy Adriano, and Travis Glenn

Past activities of the Department of Energy (DOE) have created significant environmental contamination, which can have adverse effect on all forms of life including microorganisms. On the other hand, certain groups of microorganisms are known to enhance the degradation of organic pollutants and the transformation and immobilization of heavy metals and radionuclides. Considerable amount of research has been conducted at DOE to determine the transport and fate of contaminants in soils and groundwater. Technologies have also been developed to enhance biodegradation of chlorinated organics and petroleum hydrocarbons and biotransformation of heavy metals and radionuclides at SRS. However, a deeper understanding of microbial diversity, community structure and activity is needed to better accomplish DOE missions and respond to new DOE initiatives in environmental bioremediation strategies.

Given the challenges and opportunities in the surficial and near surface environments, the overarching goals of the Molecular Microbiology and Biogeochemistry Program at SREL are:

1. To determine microbial diversity and community structure in environments having different contaminants and compare with control sites (no contamination) with similar vegetation, hydrology, and soil and sediment conditions.
2. To determine microbial activity and ecological functions in different-contaminants environments and identify microbial populations/consortia responsible for biodegradation of organics or biotransformation of heavy metals and radionuclides.
3. To understand microbial dynamics in the rhizosphere for phytoremediation of heavy metals and radionuclides.
4. To examine the interactions between microorganisms and heavy metals and radionuclide at the molecular or atomic level for a better understanding of the underlying mechanisms mediating biotransformation of these contaminants in the environments.
5. To delineate carbon flow pathways for a better

understanding of the coupling between metal/radionuclide geochemistry and microbial populations and activities fueled by different types of organic matter.

Activities toward achieving the goals above include:

- Enhancement of infrastructures for molecular DNA capabilities (Travis Glenn, Andrew Neal and Chuanlun Zhang). This includes purchases of new equipments at the Savannah River Ecological Laboratory and setting up a new DNA lab at the Aiken County Technology Laboratory in collaboration with scientists at the Savannah River Technology Center. In particular, our group is working on a protocol to quantifying functional microbial populations using real-time PCR. Our goal is to determine the specific microbial populations responsible for metal transformation in the contaminated soils.
- Enhancement of infrastructures for lipid biomarker analysis (Gary Mills and Chuanlun Zhang) and compound specific isotope ratio mass spectrometry (Christopher Romanek and Chuanlun Zhang). Lipid biomarkers provide quantitative information about the structure of extant microbial communities without the need for culturing and isolation. Lipids are also one of the most useful biochemical measures of *in situ* interactions between microbial species and their environments as lipid compositions can indicate redox, stress, or nutritional conditions. Stable carbon isotopes, on the other hand, allow tracking of carbon flow during microbial metabolisms of organic substrates. A combination of these techniques thus permits systematic study of microbial dynamics and geochemical processes during bioremediation of organic or metal contaminated soils and groundwater.
- A field investigation of microbial diversity affected by heavy metals and radionuclides in the Tims Branch and Steed Pond (Chuanlun Zhang, Andrew Neal and Paul Bertsch). Samples were collected and analyzed to test the hypothesis that microbial communities in heavy metal and radionuclide-contaminated soils will be dominated by species surviving the extreme environments. These species may have developed unique capabilities for mediating the biogeochemical transformation of heavy metals and radionuclides in the soil environments. Our goal was to enrich and cultivate these unique microorganisms from the contaminated sites and develop genetic, lipid biomarker, and isotope signature tools for detecting and quantifying these microbial populations in the soil environments.
- An exploratory study of phytoremediation enhanced by microbial communities in the rhizosphere (Chuanlun Zhang and Domy Adriano). It is hypothesized that root exudates stimulate microbial growth and affect community structure in the rhizosphere. Microbial populations adapted to heavy metals or radionuclides increase as a function of root exudate production. These microorganisms serve as focal points for metal accumulation and immobilization using cell walls as template for adsorption and transformation. Thus our goal was to determine the microbial community populations affected by root exudates, and co-existing heavy metals and radionuclides and to determine the role microorganisms play in the speciation, uptake, and immobilization of co-contaminant metals and radionuclides in the rhizosphere.

ECOLOGICAL STEWARDSHIP

Most (90%) of the Savannah River Site (SRS) is not industrialized. Nevertheless, land use in these areas contributes to various ecological risks. For example, management practices such as timber harvest, maintenance of power line rights-of-way, management of wildlife populations, or placement and operation of new facilities create potential risk because they can reduce biological or landscape diversity, increase unwanted organisms, or threaten rare or desirable taxa. Moreover, management practices may affect movement of various contaminants through the landscape. Management of the SRS requires data-intensive research and monitoring that provides meaningful land stewardship recommendations to minimize ecological risk, enhance remediation, and promote ecosystem health. This program includes research relevant to ecological land management, ecosystem structure and function, and stewardship and provides advice to the U.S. Department of Energy (DOE) on management of the SRS using concepts such as ecological integrity and risk assessment. The focus is to examine effects of land use patterns on abiotic and biotic resources in watersheds; on the communities, populations, and individuals within them (with an emphasis on rare species and those with localized distribution); and on restoration of degraded and contaminated systems.

Ecological Stewardship research program studies:

- Assess the current status of impacted, degraded, and less altered ecological systems;*
- Conduct research on various organisms as bioindicators and biodetectors of environmental contamination;*
- Examine biodiversity patterns of organisms in protected and disturbed sites;*
- Conduct research to restore damaged systems;*
- Conduct research relevant to site remediation, such as phytoremediation of contaminated wetlands and forest management to reduce movement of contaminants within watersheds; and*
- Develop recommendations for ecologically sound management of SRS land.*

The Ecological Stewardship Program interfaces with SRS management professionals to:

- Participate in decision-making activities and issue-related task groups;*
- Develop a system to better inform SRS managers about ecological issues and our knowledge base;*
- Increase transfer of ecosystem management technologies to SRS, other DOE facilities, and other land management agencies; and*
- Interface with SRS groups and professionals from other DOE sites to explore and establish new approaches to land use and ecological risk assessment.*

Impact of SRS Clean-Up on the Biological and Functional Diversity of Aquatic Bacteria

Principal Investigator: J Vaun McArthur

Bacteria are involved in all ecosystem level processes including nutrient cycling and organic matter decomposition. Furthermore, microbial processes are the primary mechanisms used for *in situ* remediation of contaminated sites. It is not clear what the chronic effect of contamination is on bacterial populations and/or functional diversity. These studies seek to detail the effects of various contaminants on the biological and functional diversity of bacteria in surface waters on the SRS. In particular we are investigating the effect of inorganic mercury on the distribution of antibiotic resistance among stream bacteria. We have begun a collaborative study with colleagues at the Medical College of Georgia. Results of these studies provide information on the ability of natural populations to respond to contaminants and the length of time required for recovery of biological and functional diversity following cleanup.

- Hired Dr. Ramunas Stepanuaskas as a postdoctoral fellow.
- Obtained a contract for a textbook on Microbial Ecology from Academic Press.
- Began new approach for screening antibiotic resistant and metal resistant bacteria using flow cytometry at the Medical College of Georgia.
- Determined the distribution of *mer* genes in Four Mile Creek using T-RFLP analyses.
- Determined the community structure of methanotrophic bacteria along Four Mile Creek using DGGE.
- Presented four papers on the results of our work at National Meetings.
- Submitted two grant proposals; one to NSF and the other to NIH.
- Submitted two microbial ecology papers to Applied and Environmental Microbiology.

Land Management in SRS Watersheds

Principal Investigators: Beverly S. Collins, J Vaun McArthur, Christopher S. Romanek, and Rebecca R. Sharitz

This program investigates land management effects on dynamics of SRS ecosystems and the plant species they harbor

in upland forests and along upland to floodplain gradients within watersheds. Land management practices, including thinning and prescribed burns for forest management, impact SRS ecosystems and shape biodiversity. At the landscape level, land management practices can affect flow of energy and materials, including contaminants, among ecosystems. For example, forest management activities, such as prescribed burns, can affect nitrogen cycling and movement from uplands to floodplains within a watershed. The form and amount of soil nitrogen can influence diversity and plant species composition within the watershed, and may affect mobility of other elements, including ¹³⁷Cs in floodplain sediments.

This research is being conducted in collaboration with the U.S. Forest Service-Savannah River (USFS-SR) to investigate aspects of forest management on key ecosystems within watersheds. It incorporates two sets of sites with specific management histories and goals.

Land management effects on small mammals, seed predation and vegetation, and nitrogen dynamics are being compared among ten upland pine and pine-hardwood forests that differ in forest management history. A specific objective of this research is to determine if forest management to enhance Red-cockaded Woodpecker (RCW) habitat influences small mammal populations, potential forest regeneration and biodiversity, and nitrogen transformations. In each site, canopy and ground layer vegetation were surveyed in 2001. Small mammal populations were estimated. Litter and seed collection traps were arrayed in summer 2001. Acorn removal by small mammals was observed over winter 2001, and oak seedling recruitment was monitored in 2002.

Forest management effects on vegetation and soil nutrient dynamics are being investigated in two watersheds. Sets of lysimeters were installed in disturbed and undisturbed plots along slopes from managed pine uplands to bottomland hardwood forest at the Meyers Branch Set-Aside and Tim's Branch. The lysimeters are sampled through the growing season, before and after forest management treatments to provide information on quantities and forms of nitrogen that are being moved down slope in surface and shallow groundwater flows. Vegetation surveys are being conducted in each site to determine forest management effects on vegetation composition. These procedures are investigating land management effects on biodiversity within the two watershed regions, including the extent to which management

practices are not sustainable.

- Site conditions associated with the absence of fire favor establishment of *Q. falcata*.
 - Canopy openness significantly decreased seedling survival, but plots that had the most soil moisture in May displayed increased survival at the end of the growing season.
 - *Q. falcata* seedling survival was greatest at the long-unburned mature pine site. However, once the seedling survived it grew equally well in all site conditions.
- $\text{NO}_3\text{-N}$ and root simulator probe (PRS) uptake of N increased from upland pine forest downslope to deciduous bottomland at Meyers Branch. PRS uptake was greater in thinned than in undisturbed forests at Tims Branch.
- From November through April, $\text{NO}_3\text{-N}$ in lysimeter samples decreased from upland pine forest downslope to deciduous bottomland at Meyers Branch. $\text{NH}_4\text{-N}$ showed a similar, but less consistent, pattern.

Products

Presentation: "The mystery of seed removal in southeastern forests: who's doing it and does it matter?" Ecological Society of America meeting, August 2002.

Recovery of Endangered Plants

Principal Investigator: Beverly S. Collins

This project provides information to enhance recovery of plant species of special concern on the SRS. The most important species is the smooth purple coneflower, *Echinacea laevigata*, which occurs in three populations on the SRS. The first two populations, Burma Road and Road B-9, have been monitored since 1988 and 1996, respectively. The third population, Tennessee Road, was located in June 1999 in Forest Compartment 85; monitoring began during summer, 2000. *Echinacea* is federally endangered, and is listed as a sensitive species by the U.S. Forest Service. *Echinacea* populations on the SRS have been exposed both to threats, including power line maintenance activities and accidental herbicide application, and to management practices that may improve the populations, including forest thinning and burning. The federally endangered designation requires DOE to avoid actions with deleterious impacts to the plants.

Although this research is focused primarily on smooth purple coneflower, it includes other plant species of concern. One of these, *Trillium maculatum*, occurs on slopes along Lower Three Runs Creek. This population, the only one known on the SRS, was discovered in 1999.

This research program combines demographic analyses with experimental manipulations to investigate maintenance and recovery of threatened plant species. It continues demographic monitoring of the three SRS populations of smooth purple coneflower. In addition, it investigates basic biology of the coneflower and the species' response to management practices. Demography of the *Trillium* population is being monitored by censusing plant size and reproductive state each year. This project contributes to DOE's obligations under the Endangered Species Act. It collaborates with and complements U.S. Forest Service-Savannah River (USFS-SR) programs for rare and endangered species.

- The Burma Road coneflower population fluctuates. It declined from 156 to 90 plants from 1998 through 2001, then increased to 106 plants in 2002. There were, on average 2.4 stems per plant in 2001.
- The Road B-9 coneflower population fluctuates. The number of stems declined from 1,929 in 1999 to 1,698 in 2000, 1534 in 2001, and 1505 in 2002. There were 461 plants in 2002, with an average 3.3 stems per plant.
- The Tennessee Road coneflower population had 204 plants and 517 stems, for an average 2.5 stems per plant in 2000. This population declined to 182 plants and 443 stems in 2001, and 181 plants and 407 stems in 2002.
- The proportions of flowering stems in the three coneflower populations were 21% in the Tennessee Road population, 5% in the Burma Road population, and 31% in the most open, Road B-9 population.
- The *Trillium maculatum* population in a sample transect increased from 50 plants in spring 2001 to 1,786 plants in 2002, then declined to 493 plants in 2003. In 2002, 20% of the plants flowered; 31 % flowered in 2003. The average age of fruiting plants was 17 years, compared to 13 years for nonflowering plants.

Wetland Restoration and Ecosystem Sustainability

Principal Investigators: Rebecca R. Sharitz, Beverly S. Collins, and Barbara E. Taylor

The U.S. Department of Energy (DOE) is committed to restoring disturbed wetlands to mitigate wetland losses and to demonstrate good land management practices. The Savannah River Site (SRS) has approximately 300 isolated depression wetlands (Carolina bays), many of which were drained by previous landowners or have been disturbed by SRS land management activities so that they no longer function as wetlands. This multidisciplinary research program seeks to determine the most cost-effective and successful methods for restoring hydrologically altered Carolina bays to sustainable wetland ecosystems for mitigation banking purposes.

Researchers from SREL and the USDA Forest Service, along with collaborators from Clemson University and the University of South Carolina at Aiken, are conducting a multidisciplinary study of management practices that may lead to cost-effective Carolina bay wetland restoration. Twenty drained bays were selected for study; of these, 16 are being restored using techniques suggested from a pilot study and 4 are controls. Additional functional bay wetlands serve as reference sites. Specific objectives are: (1) to evaluate bay restoration treatments that represent realistic land management options for the SRS; (2) to determine if bays under restoration are moving toward abiotic and biotic endpoints as determined from reference bays; and (3) to assess functional differences among land management alternatives and develop predictions of how these alternatives may provide suitable habitat for key plant and animal species.

The prescription for restoration included closing the drainage ditches, removal of woody vegetation, and planting appropriate species to establish two wetland community types: 1) open wetland meadow of grasses and herbs, and 2) forested wetland savanna. In addition, because of debate about the impacts of buffer-zone management on wetland properties and wildlife usage, two alternative strategies for managing the wetland margins are being tested. One strategy is to maintain the margins as unburned, closed-canopy mixed pine-hardwood forests, and the other is to manage them as open-canopy pine woodlands that are periodically burned. SREL studies have focused on the vegetation and wetland invertebrate communities.

Pre-restoration mapping and characterization of the hydrology, soils, and biota (including the soil seed bank) of the bays was completed in 2000. These data have shown that yearly patterns of hydrology influence plant species composition and recruitment from the seed bank. Bays, and areas within bays, that experience fluctuating water levels within a season tend to recruit from the seed bank, are rich in plant species, and lack discrete vegetation zones.

Restoration activities began in the winter of 2000/2001. Trees were harvested and removed from the bay interiors by the Forest Service, and margin treatments were established. Ditches were closed in the winter of 2001/2002. Seedlings of two wetland tree species, bald cypress (*Taxodium distichum*) and swamp tupelo (*Nyssa biflora*), were planted throughout the forested savanna bays in the winter/spring of 2001. Two species of wetland grass, maidencane (*Panicum hemitomum*) and leersia (*Leersia hexandra*), were planted in experimental blocks in the herbaceous meadow bays. Monitoring of vegetation development in planted and unplanted areas of the restoration bays began in the summer of 2001 and is continuing. Burning of pine woodland margins was conducted in spring 2003.

Aquatic invertebrates were studied extensively prior to restoration. Both macro- and micro-invertebrates were characterized in three years of bimonthly sampling. Experimental studies were conducted to determine which species persist in resting stages during the dry season and which recolonize when the wetlands are inundated.

- Hydroperiods in most of the pre-restoration ponds were short (standing water present for 20-30% of the year). These ponds had fewer species of invertebrates, for example, typically 10-20 species of microcrustaceans, compared to ponds with long hydroperiods, which supported 30-50 species. Lengthening the hydroperiod generally increases species richness, although a few taxa with resting eggs specialized to withstand extended desiccation, such as clam shrimp *Lynceus gracilicornis* and the large red calanoid copepod *Aglaodiaptomus stagnalis*, may appear less frequently or become locally extinct. Comparison with a benchmark data set for 88 ponds on the SRS resulted in predictions that herbaceous wetlands will gain more species than the forested wetlands.
- Pre-restoration invertebrate studies were published

(SREL reprint #2643).

- Species richness of herbaceous wetland species increased in most of the bays following removal of woody vegetation. Germination from the seed bank was the major source of wetland plants.
- Survival of planted tupelo seedlings has been low, likely due to drought conditions and competition with herbaceous vegetation. Survival of cypress seedlings has generally been 50% or higher.

Research on the Spatial Distributions of Biotic and Abiotic Features of Savannah River Site Reservoirs

Principal Investigator: Steven J. Harper

Scientists have historically sampled the physical and biotic components of a lake at a few locations, or even a single site, and have assumed that these limited samples are representative of the entire lake. For well-mixed, homogeneous systems such as some natural lakes, this may be reasonable. However for heterogeneous systems, such as man-made reservoirs, this approach ignores inherent spatial structure. Thus, while vertical distributions of certain features (e.g., clines in temperature, dissolved oxygen, and light) have been well studied by aquatic ecologists and limnologists, the spatial distributions of these same features in the horizontal dimension have been largely ignored. Greater understanding of the spatial context of processes operating within a system allows for increased knowledge about the system as a whole, and also provides support for sound and defensible management decisions. For example, the utilization of specific habitats or locations by target species is an important component of impact assessment, so greater understanding of the spatial distributions of organisms within local reservoirs would directly benefit ecological risk assessment efforts.

Research has been initiated to describe the spatial structure of important biotic and abiotic features of several Savannah River Site reservoirs. Objectives are to: (1) document spatial patterns of biotic (fish biomass, phytoplankton biomass, and submerged aquatic vegetation) and abiotic features (bathymetry, sediment class type, temperature, dissolved oxygen, pH, and turbidity), (2) determine how spatial patterns differ among reservoirs and change over time within a reservoir, and (3) quantify the extent to which biotic and abiotic features are interrelated. Surveys of the larger

reservoirs on the Savannah River Site were conducted throughout the year using technologically advanced sampling gear. As detailed below, hydroacoustic sampling equipment allowed the fish community, macrophytes, sediment types, and bathymetry to be sampled efficiently within limnetic regions of reservoirs. Based on preliminary results, two aspects of this work will receive greater consideration in the future. First, extensive hydroacoustic analyses will be used to develop detailed bathymetric and sediment type maps for these reservoirs. Greater understanding of the distribution of sediment texture, slope, and zones of anoxic conditions is expected to help explain variability in the concentration and seasonal dynamics of cesium that has been observed in these reservoirs. Second, the sediment-feeding gizzard shad (*Dorosoma cepedianum*) is a common species that represents the largest percentage of total fish biomass in many southeastern reservoirs. Because gizzard shad directly consume sediments and are prey to numerous terrestrial and aquatic predators, improved understanding of this species could benefit management objectives specific to the Savannah River Site. Their extremely patchy distribution (due to schooling behavior and shifts in the use of inshore and offshore habitats) requires that a spatial component be incorporated in studies of gizzard shad. Little is currently known about how biotic and abiotic factors interact to affect the abundance, size-class structure, and habitat use of this species.

- A representative of the hydroacoustic gear manufacturer (Biosonics Inc., Seattle, WA) was hosted for a three-day workshop in which the equipment was demonstrated and training was provided. Analytical methods were applied to echo-integration and fish identification techniques.
- Spatial distributions of abiotic and biotic parameters were explored using equipment (YSI 6600 multiparameter sonde and data logger) that provides rapid *in situ* measurements of temperature, dissolved oxygen, pH, turbidity, and chlorophyll-a (an index of phytoplankton biomass). Sensors were calibrated routinely in the laboratory and field to prevent drift, and independent measurements using laboratory analyses were taken to validate turbidity and chlorophyll-a estimates.
- Research on the spatial distribution of phytoplankton in L Lake was initiated as part of the NSF Research Experience for Undergraduates (REU) Program at SREL. Jill Harris, an undergraduate student at Dartmouth

College, focused her effort on understanding how the direction and strength of wind influenced the horizontal distribution of chlorophyll-a. This involved conducting repeated surveys of the reservoir throughout the spring semester. Harris gave a seminar and submitted a report describing results of this work.

- Preliminary hydroacoustic surveys were conducted on PAR Pond, L Lake, and Pond B. Multiple transducers were used to provide information about bathymetric topology (e.g., depth, distance from bank, and slope), lake-bottom sediment class types, and abundance of submerged aquatic vegetation (SAV). Having worked out logistics of these techniques, extensive transect surveys will be conducted regularly over time on the larger reservoirs. This will allow the spatial structure of each reservoir to be determined and compared with other reservoirs, as well as temporal changes in spatial patterns to be quantified. Statistical relationships among measured variables will be determined using classical and more advanced parametric and nonparametric analyses.
- A combination of mobile and fixed-position hydroacoustic surveys will be used to determine the locations, abundances, and size-class distributions of gizzard shad and other dominant fish species. This approach is expected to result in increased precision with reduced labor compared to traditional fish sampling techniques such as cove rotenoning, seining, or electrofishing.

Data Analysis in Ecology and Environmental Monitoring

Principal Investigator: Mabelle Wilson

My research interests include statistical methods in ecology, environmental monitoring, and analytical chemistry. I also provide statistical consulting to faculty and graduate students. My current research includes:

- Developing and testing a new statistic for estimating the maximal exposure in a population of animals using Monte Carlo simulation and bootstrap, and semi-parametric endpoint estimation.

(a) proposed two new statistics: the maximum likelihood estimate of the 1-1/N quantile and a statistic based on extreme value theory;

- (b) found two data sets for testing the methods: a normal and a lognormal;
- (c) wrote code for Monte Carlo simulation and parametric bootstrap to test bias;
- (d) wrote code for finding exact confidence intervals using the non-central t distribution;
- (e) presented MLE results at conference in Darwin, Australia;
- (f) presented MLE and non-central t results at conferences in Monaco and Ukraine;
- (g) submitted MLE results to Journal of Health Physics, accepted for publication;
- (h) submitted extreme value results, acceptance still pending.

- Fitting growth curves to assess determinate or indeterminate growth in turtles at the SRS using analysis of covariance, classic mathematical models, and shape-restricted covariance.

(a) researched previous work in the field and searched data base for appropriate data sets;

(b) found collaborator for the shape-restricted regression methods.

- Comparing the effectiveness of support vector machine classification to partial least squares/logistic discrimination in the classification of plants exposed to heavy metals radio-isotope contamination using high dimensional remotely sensed reflectance (hyperspectral) data;

(a) obtained new data sets for testing methods and performed the analyses;

(b) submitted paper for publication, acceptance still pending.

- Using time series analysis to model periodicity in chemical content of biomineralized tissue;

(a) obtained appropriate data set and researched time series methods;

(b) hired summer student to help perform analyses and wrote up results;

(c) submitted paper for publication, acceptance still pending.

- Constructing regression models to predict soil dispersability using several soil variables.

(a) met with scientists and researched previous work in the field.

- Developing methods of analysis for data where no distributional assumptions can be made, including the bootstrap, mixture models, and semi-parametric

methods.

- (a) met with scientists to discuss nature of the problem;
- (b) contracted for data from Chernobyl and discussed with scientists obtaining appropriate data from SRS.

- Developing methods for predicting the maximum in a stationary random process for use in predicting the maximal dose to biota over time.
 - (a) met with scientists to discuss nature of the problem;
 - (b) hired graduate student to work for the summer and obtained data from a large data set;
 - (c) researched and studied papers and methods available currently.
- Consulting: met with many graduate students and faculty at SREL and UGA to help with a variety of analyses, mostly ANOVA, spatial analysis, linear and non-linear regression, poisson regression, least squares fitting, as well as others.

Using Herpetofauna for Environmental Characterization and Risk Assessment on the SRS

Principal Investigator: J. Whitfield Gibbons

The southeastern United States has the highest biodiversity and abundance of reptile and amphibian species in North America. The U.S. Department of Energy's (DOE) Savannah River Site (SRS) is noted for a particularly rich herpetofaunal biodiversity and has been the focus of extensive inventory and research since 1951. The SRS is the largest tract of land in North America for which herpetofaunal species abundance, distribution, and diversity have been measured on a long-term basis (more than 50 years). Since the first surveys and other studies were initiated, more species of herpetofauna have been documented than have been reported from any other public land area in the United States.

The success of both risk assessment and environmental restoration/cleanup efforts begins with having an adequate knowledge of pre-disturbance organisms and ecosystems. Amphibians and reptiles are often considered important bioindicators of environmental health because certain aspects of their physiology, morphology, behavior, life history, and ecology may increase their susceptibility to environmental contaminants. The goal of my current research program is to supplement previously collected data on the ecology and spatial distribution of SRS herpetofauna with studies designed to aid DOE in SRS site characterization and risk assessment

analyses.

During FY03 the "site characterization" aspect of my program included research on sensitive species on the SRS and continued monitoring of select wetland habitats. Many of the herp species native to the SRS are officially recognized by the South Carolina Department of Natural Resources as Species of Special Concern, including the eastern tiger salamander, spotted turtle, eastern green water snake, pine snake, eastern coral snake, southern hognose snake, gopher frog, black swamp snake, and striped mud turtle. Knowledge of the distribution and abundance patterns of these species allows SREL to advise DOE on environmental issues such as environmental assessments necessary for siting of new facilities, as well as risk assessment models and forest management practices. In FY03 the following research goals were met:

- Long-term studies in relatively undisturbed areas provide invaluable information (such as population trends, effects of climate, etc.) that short-term studies cannot, leading to more sound environmental management. The monitoring of Rainbow Bay reptiles and amphibians continued for its 25th year, as recommended by the SRS Citizens Advisory Board. Monitoring efforts were accompanied by additional research at other seasonal wetlands such as Ginger's Bay (where students are examining the dispersal distances of amphibians from wetlands) and Ellenton Bay (where we are studying the export of amphibian biomass to surrounding terrestrial habitats).
- Amphibian decline is a topic of global concern. Given the possible role of disease (e.g., chytrid fungus, iridovirus) as the cause of some observed declines, we are investigating the naturally occurring microbial community in amphibians in a region where catastrophic amphibian die-off due to disease has not yet been observed.
- Populations of several sensitive species were investigated. We identified two new breeding sites for the Carolina gopher frog, continued sampling of the spotted turtle (which was recently listed as a species of management concern in SC), and initiated radiotracking studies of the southern hognose snake and pine snake.
- Research continued on developing the best methods for relocating and establishing viable populations of the gopher tortoise, a species listed as federally threatened

in several SE states. This study has direct application to the relocation of tortoises on private, state, and federal lands.

- A field study by students on how snakes respond to roads was completed. This research is important to understanding how species such as snakes respond to habitat fragmentation, and will allow DOE to make better-informed land-use decisions.
- Communicating the research results to a wider audience beyond scientists continues to be a high priority. The herpetology website (www.uga.edu/srelherp/) is frequently updated and refined. This site has been visited by more than 83,000 viewers and has generated numerous queries from interested individuals. In addition, SREL operates the Partners in Amphibian and Reptile Conservation (PARC) national website (www.parcplace.org), to serve as the nexus for herpetofaunal databases throughout the country.

Much of my program's research ties directly and indirectly to risk assessment and/or site cleanup efforts. We have previously documented biological half-lives for radionuclides and can do likewise with other chemical contaminants. Preliminary analyses have revealed the localization of selenium and arsenic in the bone of SRS turtles, the presence of lead, mercury, and cadmium in the eggs and of cesium and strontium in the muscles and bone. These and other toxic materials, widespread on the SRS, are the focus of environmental cleanup efforts. In addition, the use of historical herpetological data is proving useful in developing risk assessment plans for selected sites on the SRS. In areas where cleanup is necessary, knowledge of the "natural" community will provide the meter stick with which to measure and validate the biological success of the cleanup effort.

- We continued to work with the WSRC Environmental Restoration program on the project "Determination of SRS Distribution Patterns of Rare and Sensitive Species of Herpetofauna for Evaluating Environmental Health." The goal of the project is to augment the already existing and published databases on reptiles and amphibians of the SRS with material that pre-dates effective SREL archival systems. We estimate that as many as 300,000 data records of more than 80 species will be obtained by data-mining former data sets stored at SREL or obtained through direct contact of former site employees, students, and visiting faculty. These data will allow accurate assessment of distribution and abundance data for all

species of herpetofauna at levels that cannot be acquired currently from published material.

- In collaboration with Bill Hopkins, we completed the field portion of an experimental examination of the effects of D-Area ash basin sediments on primary productivity, zooplankton community composition, and growth and survival of larval marbled salamanders. Laboratory analyses will be completed in coming months.
- We examined the effects of a heavily used pesticide, carbaryl, on the aquatic life stage of two common salamander species (marbled and spotted salamanders). Increased concentrations of the pesticide resulted in lower survivorship, reduced growth and lipid content, and increased the time to metamorphosis of both species. Interactions between carbaryl, larval density, and species compounded these effects. Our results follow a pattern seen in a number of commonly used biocides.

All of these projects have been natural extensions of an original goal of documenting species status and trends on the SRS. One conclusion has been that the SRS is one of the most highly biologically diverse tracts of land in the Upper Coastal Plain as a consequence of long-term environmental protection of native habitats. We recommend, based on a long-standing program of ecological research on the SRS and familiarity with environmental concerns at the national level, that all activities on the SRS, especially facility development and forestry activities, be carefully assessed in terms of both short- and long-term environmental impact. A thorough environmental research program that is in concert with the environmental alterations necessary on the SRS will result in responsible environmental management, both actual and perceived.

Restoration Ecology of Highly Impacted Forested Floodplain Ecosystems

Principal Investigators: Kenneth W. McLeod and Rebecca R. Sharitz

Thermal effluents from reactor operations ceased almost a decade ago and while natural succession of the streams and flood plains is occurring, these ecosystems remain different from unimpacted reference systems. By contrasting the impacted and unimpacted systems, this research investigates the trajectory and rate of natural recovery and the similarity of the disturbed systems with natural systems, and contrasts that

with areas in which restoration has been attempted. Emphases have been placed on recovery of wetland woody vegetation and establishment of macroinvertebrate communities. Our research has the following specific objectives: (1) determine whether these ecosystems have a balanced indigenous community; (2) determine the effect of various large-scale restoration practices on the recovery trajectories of these ecosystems; and (3) experimentally determine “best” restoration strategies for specific biotic components of the system.

In an experimental planting designed to examine how a knowledgeable planter might affect forest restoration, the planter was allowed to select the species and/or planting location. Four individuals of each of five species (bald cypress [*Taxodium distichum*], water tupelo [*Nyssa aquatica*], water hickory [*Carya aquatica*], overcup oak [*Quercus lyrata*], and swamp chestnut oak [*Q. michauxii*] were planted in each plot. Two planting strategies used equal (4 x 4 m) spacing with either randomly or intelligently selected species and the third strategy used both intelligently selected species and planting location. Plots had an obvious elevation gradient with an intermittent stream on one side and located in the Fourmile Branch delta containing ash, willow, and pine saplings that invaded the site over the previous 15 years. Thus, the planter could exploit the differing species characteristics relative to the relative elevation and shade gradients. Survival, diameter, and height have not differed significantly based on planting strategy over the seven years since planting. Overall survival of water tupelo declined to 25%, while survival of the other species has exceeded 75%. Overcup oak had the greatest height and diameter growth. Intelligent planting did not increase survival or growth in this field experiment, conducted through an extended drought, but these results could be significantly different in times of normal rainfall.

Restoration of Longleaf Pine/Sandhills Communities

Principal Investigators: Kenneth W. McLeod, Beverly S. Collins, Rebecca R. Sharitz, and Steven J. Harper

In the southeastern United States, vast areas were once covered by longleaf pine-dominated communities. Most of the original acreage of these fire-maintained communities has been urbanized or converted to agriculture or forestry. In the sandhills communities that remain along the Fall Line, fire

suppression has allowed less fire-tolerant oak species [turkey oak (*Quercus laevis*), scrubby post oak (*Q. margaretta*), and bluejack oak (*Q. incana*)] to increase in importance while longleaf pine (*Pinus palustris*) has declined. Natural stands of the various longleaf pine community types are relatively uncommon. Reductions in the extent of these communities have limited several plant and animal species to the extent that they currently require federal protection. This program conducts research to guide land managers in management and restoration of the under-represented longleaf pine/sandhills communities.

Research in this program is currently being leveraged by two grants from the Strategic Environmental Research and Development Program (SERDP) to SREL investigators Beverly Collins, Rebecca Sharitz, Steven Harper and others. These grants support research in longleaf pine and sandhills sites at Ft. Benning near Columbus, GA and Ft. Gordon near Augusta, GA. Many of the overall research results from this program are also being reported in the annual reports for each of those grants.

- An extensive collection of spatial data for Fall Line sandhills and longleaf pine areas has been acquired for the SRS and the two military installations. Aerial imagery, maps, soils data, information on land management and other factors of interest have been incorporated into a GIS framework to develop spatial data layers. These GIS layers are being used to select sites for intensive field surveys.
- Field metrics for discriminating sandhill communities (oak-dominated) from surrounding longleaf pine communities have been developed, based on abundance of sandhills-dominant trees, and canopy and soil characteristics. These metrics are proving effective at discriminating among sandhills and longleaf pine communities on the ground and in confirming initial identification from GIS analysis.
- Ten threatened and endangered (TES) plant species have been chosen for study of habitat and population characteristics. Surveys were initiated in spring 2003.
- Two sandhills sites were included in a study of seed predation by small mammals in habitats ranging from slope deciduous forests to upland pine forests. Among these habitats, sandhills sites had the greatest shrub cover and the least removal of southern red oak (*Quercus falcata*) acorns by small mammals, primarily cotton mice

(*Peromyscus gossypinus*). Southern red oak seedlings planted in April continue to thrive, giving some evidence that species establishment by seeding or planting seedlings might be successful. There was also considerable soil moisture variation related to seasonal activity of the vegetation.

Phytoremediation of Contaminants in Constructed and Natural Wetlands

Principal Investigators: J Vaun McArthur, Beverly S. Collins, Kenneth W. McLeod, and Rebecca R. Sharitz

Wetlands on the SRS and at other DOE sites contain mixtures of chemical pollutants, including volatile organic compounds, metals, and radionuclides. Current cleanup technologies are expensive. Technologies that are less invasive and expensive, but still stabilize and contain contaminants *in situ*, would be highly desirable. Various plant species have been shown to stabilize, filter and/or extract excess nutrients, organic solvents, metals, and radionuclides. Thus, plants can play a major role in stabilizing and remediating wetlands.

In addition to the stabilization and extraction functions of plants, their use of water will reduce migration of contaminated groundwater by reducing the amount of downward water movement. Further, the structure and chemical environment of plant roots provides favorable conditions for fungi and microorganisms that can degrade contaminant compounds. Plant-based remediation could be used in situations where contamination level is low, risk to the public is low, and where slower, low-cost cleanup can be substituted for an immediate and high-cost cleanup.

Our objectives are to: (1) investigate the tolerance and uptake rates of contaminants by various native wetland species, (2) characterize the microbial assemblages associated with each native plant species, and (3) determine what combinations of plants/microbial assemblages best degrade contaminants.

- Water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) seedlings were planted in the F-Area seep line in 1997 in an area that had tree mortality beginning in the late 1970s. Since then, leaves have been sampled and seedling survival has been determined annually. Bald cypress survival has continued to be much

greater than water tupelo. Water tupelo continues to be stressed as indicated by lack of growth and die back of the stem. Bald cypress fared better with an increase of height this season by an average of 40 cm (range 10-71 cm).

- Concentrations of aluminum, cobalt, manganese, and nickel in water tupelo leaves were 548, 339, 4673, and 29 mg/kg, respectively. These are 16, 339, 20, and 9 times greater than in bald cypress, respectively. Bald cypress leaves had greater sodium concentrations (1118 vs. 237 mg/kg). These differences between species and elements are consistent with uptake experiments conducted in the greenhouse under more controlled environmental conditions with Mn- and Co-amended soils.
- Of particular interest this year was a 5-fold increase (from 20 to over 100 mg/kg) in the boron concentration in leaves of both species. Source of the boron is unknown.
- Bald cypress and water tupelo were planted in an acidic, wet area of the D-Area coal basin in 2001. Survival was good for bald cypress (7 out of 8 trees alive) but not for water tupelo (all 13 trees died). Bald cypress is a more robust tree than water tupelo and may make a good candidate for phytoremediating the wetter areas of an acidic coal ash basin.
- Experimental constructed treatment wetland mesocosms (CTWs) were used to evaluate the potential roles of native wetland plants and bacterial assemblages in remediating acidic, metal-contaminated runoff waters from the D-Area coal pile runoff basin.
 - Four native wetland plants (*Juncus effusus*, *Pontederia cordata*, *Nymphaea odorata* and *Myriophyllum aquaticum*) were shown to concentrate metals in shoot and root tissues and help remediate acidic metal-contaminated water for two growing seasons. Patterns of elemental uptake and concentration reflected plant life form, element concentrations in water and sediments, and role of the elements in plant physiological processes.
 - Water quality was not significantly different between mesocosms with plastic plants (providing colonization surfaces for bacteria) and those without plants. However, both of these treatments differed from tanks containing real plants.
 - Bacterial assemblages associated with real and

plastic plants differed both among deep and shallow water mesocosms and seasonally.

History of Environmental Change on the Savannah River Site

Principal Investigators: Barbara E. Taylor and Mark J. Brooks (Savannah River Archaeological Research Program)

We are using palaeoenvironmental records to clarify regional and local responses of climate and landscape to change in global climate during the Pleistocene and Holocene. Organic carbon, pollen, and siliceous microfossils provide records from the basins of Carolina bays and other isolated wetlands; sediment stratigraphy and archaeological sites provide records from adjacent ridges and dunes. Our current studies focus on three times of change: (1) episodes of warmer and moister climate resulting in development of Carolina bays during the mid- to late Pleistocene; (2) a hydrologic threshold during the mid-Holocene; and (3) a possible moister episode beginning in late prehistoric times. This research contributes to our understanding of the history of climate and the responses of southeastern ecosystems. Because the region has been well populated with humans since at least 13,000 yr B.P., these changes are important to human history, as well as to ecological history. Current collaborators include: Dr. Chris Clement, South Carolina Institute of Archaeology and Anthropology; Dr. Evelyn Gaiser, Florida International University; Dr. Robert Gardner, University of South Carolina; Dr. Andrew Ivester, West Georgia State University; Peter Stone, South Carolina Department of Health and Environmental Control; and Dr. Eric Wright, Coastal Carolina University.

- Optically stimulated luminescence (OSL) has enabled us to date the formation of inland dunes and sand rims Carolina bays on the southern Atlantic Coastal Plain. The ages for bays, including Flamingo Bay and Bay 40 on the SRS, indicate episodes of moister climate around 110,000, 80,000 and 40,000 years before present. The poster "Carolina bays and inland dunes of the southern Atlantic Coastal Plain yield new evidence for regional paleoclimate" by A. H. Ivester, D. I. Godfrey-Smith, M. J. Brooks, and B. E. Taylor was presented at the Geological Society of America Annual Meeting in Denver, Colorado.
- Chemical and microscopic analyses of biogenic silica provided further documentation of major shifts in

hydrology of Peat Bay on the SRS, including a time of wetter conditions around 4600-3800 years before present.

- A series of AMS radiocarbon dates revealed that a core from a spring at Fort Jackson, South Carolina, contains sediments extending to 21,000 years before present, the time of the last glacial maximum. The most exciting part is a sequence with well-preserved pollen from the early to mid-Holocene time, when pines are hypothesized to have replaced oaks as the dominant tree species. This transition has been poorly dated elsewhere in the Upper Coastal Plain. A proposal by B. E. Taylor, M. J. Brooks, and C. Clement for further work, including pollen analyses, has been approved pending availability of funds from the natural and cultural resource management program of the South Carolina Air National Guard.

ECOTOXICOLOGY, REMEDIATION, AND RISK ASSESSMENT (ETRRRA)

The U.S. Department of Energy (DOE) has responsibility for a number of contaminated sites resulting from more than 40 years of operations. There is a clear need for information about the fate and effects of these contaminants and effective strategies for site remediation or cleanup. To address these needs, the ETRRA Group conducts research on ecotoxicology and remediation, provides data and information for use in risk assessment, and interfaces with Savannah River Site (SRS) environmental management and risk assessment professionals.

ETRRRA's research activities include:

- Studies of the fate and effects of contaminants at all levels of ecological organization;*
- Evaluation of the effectiveness of remediation activities;*
- Studies relevant to SRS environmental professionals, including risk assessors;*
- Generation of ecological and ecotoxicological baseline data; and*
- Development and application of new methods for assessing impact, risk, and recovery.*

ETRRRA interfaces with SRS management and remediation professionals by:

- Supporting environmental management and risk assessment activities;*
- Integrating and synthesizing Savannah River Ecology Laboratory information applicable to SRS environmental management and risk assessment; and*
- Providing scientific and technical expertise in ecological and toxicological fields.*

ETRRRA communicates with SRS and other environmental professionals by:

- Promoting interactions between SRS professionals and outside experts;*
- Writing and editing books and documents on ecotoxicology, remediation, and risk assessment, which contribute knowledge relevant to SRS and other DOE site activities;*
- Publishing high quality research relevant to SRS goals in peer reviewed journals; and*
- Presenting research findings at local, national, and international forums.*

Cycling of Mercury in SRS Waters and Accumulation by Fish and Wildlife; Effects of Heavy Metals on Biota

Principal Investigators: Charles H. Jagoe and I. Lehr Brisbin

This program addresses fundamental scientific questions through research on the processes that control mercury speciation and bioaccumulation in fish and wildlife, and by studies of the biological and ecological consequences of chronic, sublethal mercury exposure. By documenting mercury and selected trace metals in fish and other biota over time, and identifying the key processes that control accumulation of metals in biota, impacts of land management and stewardship activities that might affect negatively impact metal cycling can be minimized. Identification of key processes controlling speciation and bioavailability are also crucial to future remediation efforts in contaminated areas. Field and laboratory studies within this program also explore potential effects of ongoing metal exposure on SRS fish and wildlife. This program closely integrates with Monitoring and Risk Assessment for the Endangered Wood Stork program and the Studies of the Fate and Effects of Nuclear Industrial Contaminants in Wildlife of the Savannah River Site program, by providing data relevant to considerations of dietary intakes by fish, wildlife, and human consumers. This program differs from the others by focusing on the basic mechanisms by which mercury enters and accumulates through food webs, and the potential effects of mercury and other metals on exposed organisms. Mechanisms of accumulation are dependant on transformation processes (methylation and demethylation) that occur in soils and waters and control the concentration and availability of methylmercury, the major form that accumulates in biota. This program has documented mercury concentrations in fish and other organisms inhabiting SRS reservoirs, and the effects of various management activities on contaminant concentrations and cycling. It has also provided information on mercury in organisms living in Carolina bays, and has shown that differences in mercury concentrations in biota over spatial and temporal scales are influenced by water chemistry, changes in water level, flooding and drying of soils, and other factors. This program has also contributed to the evaluation of potential risks of dietary mercury exposure to wildlife, including threatened and endangered species such as the Bald Eagle and Wood Stork.

This program also supports regulatory compliance and ecological risk assessment needs at the SRS by producing

information on the cycling, uptake, and effects of mercury and other trace metals in SRS terrestrial habitats, reservoirs, waters, and wetlands. Site activities involving the future of L-Lake or other reservoirs, or Carolina bay restoration, may also alter mercury bioavailability, raising regulatory and risk assessment issues involving the U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and South Carolina Department of Natural Resources.

- A study of mercury accumulation and effects in crayfish was completed. Crayfish fed diets based on fish from SRS reservoirs accumulated mercury in their tissues, and very little of this was excreted or lost during molt. Crayfish that accumulated mercury on this diet showed behavioral changes that might make them more susceptible to predation in the wild. Crayfish exposed to environmentally realistic mercury concentrations accumulate this metal, and may serve as a vector carrying mercury into terrestrial food webs.
- Studies were begun on the effects of dietary mercury on growth, mortality and metamorphosis in frog larvae (tadpoles). Preliminary data suggest that mercury in the diet may affect tadpole growth and survival. These studies will continue and be completed in the coming year.
- Analysis was completed on bass that were collected from SRS reservoirs to evaluate the potential for maternal transfer of mercury into fish eggs and larvae. Mercury concentrations were relatively low in eggs compared to other tissues in the fish. Egg production is a minor route of mercury excretion in adult bass. A similar conclusion was reached from analysis of egg and tissue samples from American alligators. Mercury in fish accumulates with age via the diet, and the initial contribution by maternal transfer is quite small.
- A joint study with WSRC and University of South Carolina, Aiken researchers examined mercury in Asiatic clams from the Savannah River and tributary streams. Water from small tributaries that drained coastal lowland marshes tended to contain higher methylmercury concentrations than water in the main river channel. This pattern was also seen in Asiatic clams inhabiting the mouths of tributaries versus the main river channel. These results indicate the importance of mercury methylation in swamps and wetlands as a net source for mercury in the biota of the Savannah River.
- Research continued on accumulation of mercury in the biota of wetlands constructed for effluent remediation,

on the impacts of repeated flooding and drying of sediments on accumulation of mercury and other metals by crayfish, and accumulation of mercury in fish-eating birds.

Ecotoxicology: Trophic Transfer and Sublethal Effects of Trace Elements on the SRS

Principal Investigators: Drs. William A. Hopkins, Brian P. Jackson, and Justin D. Congdon

Coal combustion accounts for 90% of fossil fuel-related wastes produced in the U.S. and constitutes a major category of waste production on the SRS. In D-Area, coal ash is discharged into open settling basins that are located approximately one-quarter mile from the Savannah River. Effluent from the basins enters Beaver Dam Creek, a tributary of the river. High levels of trace element contamination (As, Cu, Cr, Cd, Se, Sr) occur in the water, sediments, and biota in the settling basins and downstream areas. Among the organisms that accumulate trace elements are alligators, softshell turtles, slider turtles, water snakes, largemouth bass, several sunfish species, bullfrogs, toads, crayfish, and fresh-water clams. Our research seeks to identify the extent of contamination of organisms inhabiting the D-Area Ash Basins, and to help explore less expensive remediation alternatives. The specific goals of our research are to: (1) identify organisms that have elevated trace element levels and any associated morphological, physiological, and behavioral abnormalities; and (2) identify the amounts and routes of contaminants transferred from the sediments to high trophic level organisms. Based on our research over the last year in D-Area, we:

- Developed laser ablation-ICPMS techniques for use as a nondestructive indicator of contaminant exposure. We found that LA-ICPMS can be a powerful tool for predicting an organisms previous exposure to As and Se. The work was recently published (SREL reprint #2683).
- Determined that trophic and maternal transfer are significant routes of Se mobility in high trophic level predators such as snakes and birds. Depending on the concentrations of Se ingested, offspring viability of affected females is at risk. This work resulted in two publications this year (papers *in press* in *Archives of Environmental Contamination and Toxicology* and *Ecotoxicology and Environmental Safety*).

- Found that in direct contrast to most organisms examined to date, some vertebrates are quite tolerant of trace element exposure. Field and laboratory work on the eastern mosquitofish (*Gambusia holbrooki*) revealed that fish experiencing lifelong exposure to coal combustion wastes, and Hg alone, exhibit normal physiological and reproductive performance. The work resulted in two publications this year: (SREL reprint #2653 and one paper *in press*).
- Found that different species of anurans breeding in coal ash impacted systems vary considerably in their responses. We hypothesize that some of the variability in response may be due to the length of the larval period; animals with longer larval periods are exposed longer, perhaps resulting in more severe effects. The work is currently in review.
- Found that ash disposal not only has direct effects on vertebrates, but also has indirect health effects mediated by detrimental effects on food resources. When ash reduces the amount of food available, animals experience combined nutritional and toxicological stress. The work is currently in review.

Monitoring and Risk Assessment for the Endangered Wood Stork

Principal Investigators: I. Lehr Brisbin, Jr. and Charles H. Jagoe

To assist the U.S. Department of Energy (DOE) in their efforts to preserve and manage their natural resources, specifically the federally endangered Wood Stork (*Mycteria americana*), SREL continued to monitor the SRS for the frequency and location of stork use and to determine contaminant concentrations (primarily mercury) in stork prey. Monitoring efforts focused on active, historical, and potential SRS stork foraging sites (typically Carolina bays and other bay-like wetlands), including reservoir systems potentially impacted by site management activities. Most "natural" SRS wetlands are not surveyed for contaminants by other site monitoring programs, and this project provides comparisons of mercury concentrations in small reservoir fish with similar-sized fish in wetlands (bays) not thought to receive direct (point-source) pollution. Local stork colonies were monitored for observable contaminant effects and will be a source of tissues to analyze for contaminant detection. Contaminant levels (mercury) in

nestlings from these local stork colonies were compared to levels in nestlings from more distant colonies. SREL has a long-term (7+ year) database concerning mercury levels in stork nestlings to assess potential impacts of region and climate conditions on mercury uptake.

- In 2002, Wood Stork use of many SRS wetlands was extremely low, due to the continued impact of the long-term (3+ years) drought that resulted in the complete drying of many of the wetlands that storks use as foraging habitat.
- In 2002, project personnel published peer reviewed manuscripts concerning potential threats of mercury to storks that forage in SRS depression wetlands and coastal habitat use by storks during the non-breeding season.
- Alessandra Seccomandi, a doctoral student from Brazil, worked at SREL comparing the molecular genetics of North American vs. South American Wood Storks.

Risk Assessment of Mixed Waste: Synergistic Effects on Individuals and Populations

Principal Investigators: Tom Hinton and William Hopkins

Processing nuclear materials and other industrial activities such as steam and energy generation have produced mixed wastes at many locations on the Savannah River Site (SRS). Particular categories of waste (i.e., radionuclides such as cesium and strontium, and chemical contaminants such as arsenic, cadmium, mercury, and selenium) can be associated with specific processes or activities. However, once released into the environment, contaminants of various types and from many sources can result in complex mixtures that may create new environmental problems. Assessments of risk to non-humans associated with environmental contamination often focus on a single type of pollutant, but risk assessments based on a single stressor may be inadequate to describe the actual threats to individuals or populations. A review of risk assessment within the DOE Environmental Remediation Program, conducted by the National Academy of Sciences, stated: "If DOE or other stakeholders desire greater utility and less potential bias in the risk assessment process, then greater precision, more research, and more data are required [on] health effects of mixtures of wastes."

The goals of this research program are to: (1) identify sites

where synergistic effects of mixed contaminants such as trace elements and radionuclides (cesium and strontium) pose problems for organisms; (2) identify which suites of contaminants are associated with morphological, physiological, behavioral, and genetic abnormalities; and (3) identify the amounts of mixed wastes that cause detectable abnormalities.

- Developed laboratory model [fence lizard (*Sceloporus*)] for studying the effects of mixed wastes on terrestrial ectotherms. The fence lizard is a terrestrial predator found across much of the United States and on most DOE sites. It feeds on terrestrial invertebrates, which can serve as important trophic vectors of trace element contamination. Over the last year, we have developed techniques for administering trace elements (i.e., Se and Cd) via a simplified laboratory food chain. Future work will examine methods of administering other trace elements as well as radionuclides.
- We conducted a large-scale pilot experiment at our Low Dose Rate Irradiation Facility. The experiment examined population level impacts to fish exposed to 1) 350 mGy d⁻¹ of gamma irradiation, 2) a cadmium-contaminated diet, 3) gamma irradiation and a cadmium-contaminated diet, and 4) un-irradiated control animals on a clean diet.

Studies of the Fate and Effects of Nuclear Industrial Contaminants in Wildlife of the Savannah River Site: Assessments of Ecological and Human Health Risks

Principal Investigators: I. Lehr Brisbin, Jr. and Charles H. Jagoe

Concentrations of radiocesium (¹³⁷Cs) and non-nuclear contaminants (particularly mercury and other heavy metals) have been determined in both free-living SRS wildlife and "sentinel animals" released into contaminated SRS habitats. Sentinel animal studies, for example, can be undertaken to study factors controlling the uptake and concentration of these contaminants through controlled/manipulative experimentation using species such as bantam chickens, game farm mallard ducks, and radio-transmitter-equipped box turtles. At the same time, assessments of biomarkers indicative of contaminant impacts upon these animals can be made and this information can then be related to the contaminant body

burdens of the same individuals. This work is focused mainly on species utilizing aquatic food chains of the SRS, particularly those of the Site's abandoned reactor cooling reservoirs (Par Pond, L-Lake, and Pond B). An emphasis is also placed upon game species such as deer and hogs that may be consumed by the public after being harvested on the Site (e.g., during SRS deer hunts). Concern is also directed toward highly mobile species (e.g., doves, waterfowl) that may become contaminated and then quickly leave the Site and thus serve as potential vectors of SRS contaminants to the public. These studies are designed to provide long-term baseline data of the kind required for both ecological and human health risk assessments for future SRS activities and include basic species ecology, behavior, and movement studies. Among these activities is the eventual need to consider draining one or more SRS reactor cooling reservoirs, as was proposed as part of the SRS river water shutdown, and the cleanup of contaminated waste sites under Federal Facilities Agreement with the state of South Carolina. Recent advances in the areas of Geographic Information Systems (GIS) technology, radioecology, molecular genetics, and ecotoxicology are employed. Studies of the basic ecology and natural history of these game species on the SRS, while essential for evaluating the risk to these species from Site contaminants and other activities, also provide information on the status of these populations on the Site. This information is shared in turn with those groups, such as the U.S. Forest Service, which are charged with managing these populations and other natural resources on the site.

- A manuscript was published that described the use of radiotelemetry techniques to study the movements of raccoons in the vicinity of radiocesium-contaminated wetland habitats on the SRS; the potential for raccoons to serve as a vector of this radionuclide to the food chain of the off-site hunting public was examined.
- A final year of trapping small mammals in the Tim's Branch CERCLA site has been completed, and data analyses have begun on the resulting 2-year data set for uranium, nickel and other trace metals in these animals.
- A doctoral dissertation was completed in which spatial models were developed for risk assessments involving raccoons and feral hogs at the SRS. These models were ground-truthed used long-term (> 30 years) survey data and radiotelemetry studies of the movements and behavior of both of these species at the site. At the June commencement ceremonies of the University of South

Carolina, this dissertation received the prestigious School of Public Health 2003 Doctoral Achievement Award.

- All field collections have been completed for a study of spatial and demographic patterns of mercury contamination of American alligators throughout their range in the southeastern United States. These samples are now undergoing laboratory analyses for eventual comparison with similar data for mercury in alligators from the SRS, where contamination levels in this species have been shown to often be considerably elevated above background.

Phytoremediation and Enhanced Monitored Natural Attenuation: Plant-Based Technologies to Remediate Contaminated Soils and Plumes

Principal Investigators: Domy C. Adriano, Kenneth W. McLeod, Gary Mills, Tracy Punshon, and Lee Newman

Plants can play a major role in remediating and rehabilitating degraded soils and plumes. Various species have been shown to stabilize, filter, and/or extract excess nutrients, organic solvents, metals, and radionuclides. Plant roots can also stabilize and improve soil structure, thereby decreasing erosion. Transpiration by plants will reduce leaching of contaminants to the groundwater by reducing the amount of downward water movement. A favorable microenvironment exists in the plant rhizosphere for fungi and microorganisms to degrade toxic organic compounds and transform inorganic contaminants. This can enhance natural attenuation. Plant-based remediation could be used in situations where contaminant concentration is low, risk to the public is low, and where slower, low-cost cleanup technologies can be substituted for more invasive, immediate, and high-cost cleanup. These technologies can be especially appropriate when dealing with buried mixed wastes as plant roots absorb and transform/degrade both organic and inorganic constituents.

Objectives of our research are to: (1) investigate the tolerance and uptake rates of various contaminants by native and economic plant species; (2) explore the suitability of plants to remediate various contaminated soil and/or plume settings directly or indirectly through the production of root exudates that contain low-molecular weight organics and carbohydrates that serve as electron donors or complex with inorganic

contaminants, and (3) evaluate the addition of soil amendments in optimizing plant uptake of certain contaminants (e.g., metals and radionuclides).

- The high potassium and cesium uptake characteristics of amaranth species has been investigated at Chernobyl. At SREL, three varieties of high biomass-producing amaranth were grown in mesocosms containing an acidic bottomland soil amended with 0, 5, or 10% weathered ash. Growth of amaranth was statistically unaffected by any concentration of fly ash addition, but the Jamican calliloo variety had slightly greater growth than either the Molten fury or Mercado varieties. Of particular interest, was the high potassium (>4%) and zinc (>2,000 ppm) levels in the leaves of all three varieties, making these amaranth varieties promising candidates for phytoremediation of cesium or zinc contaminated areas.
- Monitored Natural attenuation (MNA) uses organisms and their processes to reduce the bioavailability and/or concentration of contaminants to levels that no longer pose a long-term risk to ecological health. We have initiated a study evaluating the attenuation of TCE by native wetland vegetation in a contaminated ground water plume at the C-Area Burning Rubble Pit (CBRP). Woody (deciduous, coniferous and phreatophytes), and understory plants (including aquatic species) were collected from two selected wetland areas within the documented TCE plume isopleths. Results indicate that uptake of TCE by native vegetation is minimal, passive, and sporadic with regard to space and time. The majority of sampled plants did not contain TCE. An exception to this general trend was the detection of TCE in lignified vascular tissue of a mature loblolly pine growing at the distal end of the plume near Four-mile Creek. The TCE metabolite, trichloroacetic acid (TCAA), was detected within leaf tissues of sweet gum and some aquatic macrophytes, but was not detected within vascular or root tissue. Over 100 black willows (*Salix nigra* L.) were planted at an appointed site within contaminated groundwater seep zones, to investigate the ability of fast-growing, woody phreatophytes to enhance TCE attenuation.
- Studies of nickel, cadmium, and zinc uptake have been completed for a wide range of hybrid poplars (*Populus spp.*), concentrating on those that have been used previously for phytodegradation of trichloroethylene (TCE). Considerable clonal differences have been shown between clones within the same species, and there is

evidence to suggest that their different tolerance abilities may allow them to either facilitate or prevent phyto-extraction to meet the needs of the end user. Major findings of this research indicate a clone-specific response to metal uptake, both of metals supplied singly and those supplied in tandem with another metal intended to mimic a mixed waste situation. Hybrid poplar clones differ, often up to an order of magnitude, in the amount of heavy metal they can accumulate before phytotoxicity is observed, confirming the importance of clone selection in plant-based remediation studies. Studies also indicate that heavy metal toxicity—encountered at mixed waste contaminated sites—will almost definitely negate phytoremediation processes which involve the transpiration stream, such as the uptake of volatile organic compounds. Studies have shown that phytotoxicity of some clones of *trichocarpa x deltoides* (TD) results in retarded growth and almost a complete cessation of the characteristically robust transpiration stream. Comparisons between clones exposed to metals also suggest that TD clones are by no means the most favorable clone choice for use in remediation of toxic metals, and the clones *nigra x maximowczii* (NM) and *deltoides x nigra* (DN) produced more biomass and accumulated more metals than TD clones.

Aquatic Invertebrates and Trophic Pathways for Contaminants

Principal Investigator: Barbara E. Taylor

Because invertebrates constitute the bulk of the primary consumers in most aquatic systems, they can play an important role in the trophic transfer of contaminants to fish and other secondary consumers. We have developed several collaborative projects to apply our expertise about members of this diverse group of organisms to studies of contaminants on the SRS. These studies address specific questions about dynamics of contaminants and further general understanding of ecological processes in southeastern aquatic and wetland systems. Current projects concern radionuclides in the abandoned cooling reservoirs and coal combustion wastes at D-Area. Collaborators include W. Hopkins, K. McLeod, J. Pinder, B. Collins, R. Sharitz, T. Hinton, and B. Jackson.

- Using stable carbon and nitrogen isotopes as indicators

of trophic position, we inferred that the snail *Helisoma trivolvis* at Pond 4 feeds mainly on epiphytic algae, rather than on emergent or floating macrophytes. This result is important for understanding pathways for movement of contaminants, such as radiocesium, into the biota. Earlier work showed that stable cesium, experimentally added to Pond 4 as an analog for radiocesium, accumulated rapidly in tissues of the snails. A poster on “Contaminant uptake by littoral and planktonic invertebrates in a small southeastern impoundment” by A. E. DeBiase, B. E. Taylor, J. E. Pinder, and T. G. Hinton was presented at the Annual Meeting of North American Benthological Society.

- M.S. student Jamie Williams at the Institute of Ecology, University of Georgia, initiated field studies at a wetland downstream of the coal fly ash receiving basins in D-Area on the SRS. The project will investigate the contributions of trophic transfer and direct uptake to contaminant burdens of fish and larval amphibians exposed to coal combustion wastes.
- We initiated field studies in June on aquatic and wetland invertebrates at the 488-D Wetland, a forested floodplain that received a substantial quantity of coal fly ash from the 488-D Ash Basin several decades ago. The ash is now buried. Contaminants of potential concern include arsenic, selenium, and vanadium. We are quantitatively sampling composition and abundance of substrate-dwelling invertebrates at stations with and without buried ash. We are also collecting and preparing tissues of earthworms and land snails for contaminant analysis. This research is part of a project funded by SRS Environmental Remediation program on “Trace element distribution and impact on plant and animal communities in the D-Area swamp ash plume.” (K. McLeod, B. Collins, B. Taylor, W. Hopkins, R. Sharitz, and B. Jackson).

RADIOECOLOGY

Four decades of nuclear production have resulted in the releases of radioactive materials into many ecosystems of the United States and Eurasia. There is a need for more detailed information on the fate of radioactive materials and their effects on individual organisms, populations, and communities. Knowledge concerning the effects of low dose-rate radiation is particularly lacking. The need for this information has been cited in reviews by the U.S. Department of Energy (DOE) and the National Academy of Sciences. Such information is needed for any efforts to plan for the downsizing and/or closure of any lands currently closed to public access at the SRS. It is also essential for regulatory programs of various state and federal agencies. The study of radiation in the environment has been a central tenet for Savannah River Ecology Laboratory (SREL) researchers for many years. In its early years SREL was called the Institute for Environmental Radiation, and to this day, SREL remains one of very few academic institutions committed to the discipline of radioecology.

Current directions for radioecological research at the Savannah River Ecology Laboratory address:

- Environmental distribution, uptake, and transport of radioactive contaminants on the SRS, meeting DOE needs for compliance and predictions of risk;*
- Health effects upon nonhumans from mixed wastes;*
- Dose assessments for plants and animals exposed to environmental radiation;*
- Genetic changes in response to previous and current plant operations;*
- Assessment of environmental problems associated with radionuclides in the environment; and*
- Development of bioindicators as a cost effective way for assessing risks.*

Environmental Distribution, Uptake, and Transport of Radioactive Contaminants on the Savannah River Site: Meeting DOE Needs for Compliance and Predictions of Risk

Principal Investigators: Thomas G. Hinton, Anna C. Knox, and Bonjun Koo

The objectives of this research are to help document current radioactive contaminant levels on the Savannah River Site; understand the mechanisms and processes that govern radionuclide transport sufficiently that accurate long-term predictions of contaminant transport and fate can be made with quantifiable certainty; and determine current as well as future human and ecological risks from radioactive contamination.

- Data analyses are nearing completion on a research project in which we added a tracer of stable cesium to an entire lake. We are determining the rate of Cs transfer through various components of the lake ecosystem. The data will be useful in simulation models that predict the transfer of Cs in aquatic systems.
- We are continuing our research on the addition of illite minerals to ¹³⁷Cs-contaminated wetlands. The amendments bind ¹³⁷Cs and make it less bioavailable, yet do not destroy the sensitive wetland, as do traditional remediation methods. The technique has been very successful, reducing ¹³⁷Cs concentrations in water some 40-fold, with 2- to 3-fold reductions in plants and fish. This year we are adapting the technique to flowing streams.

Technical Reports: Hinton, T. G., A. S. Knox, and D. I. Kaplan. 2002. Field Deployment of an *in situ* Remediation Method for ¹³⁷Cs-Contaminated Wetlands. WSRC-TR-2002-00516, Rev. 0. Westinghouse Savannah River Company, Aiken, SC.

Presentations (underline indicates presenter): Hinton, T. G., A. S. Knox, D. I. Kaplan and B. T. Butcher. Immobilization of cesium-contaminated sediments through the addition of illite clays. *The 12th Annual West Coast Conference on Contaminated Soils, Sediments and Water*. March 21-25, 2002, San Diego, CA. Soil and Sediment Contamination 11 (3):473-489.

Posters (underline indicates presenter): Hinton, T. G., J. E. Pinder, E. W. Whicker, L. Marsh, J. Joyner, D. Coughlin, Y. Yi, and J. Gariboldi. 2002. Comparative kinetics of cesium from whole-lake, limnocorrals, and laboratory-scale experiments. *Society of Environmental Toxicology and Chemistry Annual Meeting*. Salt Lake City, Utah 16-20 November 2002.

Dose Assessments for Plants and Animals Exposed to Environmental Radiation

Principal Investigators: Thomas G. Hinton, Travis C. Glenn, and Mabelle Wilson

Accurate dose assessment is critical for addressing biological effects associated with radiation by way of dose-response relationships. These dose-response relationships apply to a variety of end points, including DNA damage, cellular physiology, fertility, viability, and population/ community dynamics. Development of accurate methods for assigning absorbed dose could prove to be very cost effective for cleanup activities on the SRS and other sites. Current tables and mathematical approaches for extrapolating dose from exposure values are usually overly conservative. Knowledge of an actual dose could exempt some regions from cleanup requirements or serve to downgrade polluted areas to lower priority or less stringent control measures. Over a decade ago, the International Atomic Energy Agency (1992) conducted a literature review of radiation effects to biota and suggested that reproduction was a more sensitive endpoint than mortality, and offered, as a general guideline, that if maximally exposed individuals receive dose rates less than 10 mGy d⁻¹ then populations of aquatic organisms will be protected. The U.S. Department of Energy (DOE) recently adopted 10 mGy d⁻¹ as a criterion in their technical standard for DOE Order 5400.5 (Radiation Protection of the Public and the Environment; DOE 2002). However, more recent reviews suggest that reproduction in fish can be negatively affected at lower dose rates (2 to 5 mGy d⁻¹; Sazykina and Kryshev, 2003), and that threshold levels for the first negative changes in immune system responses occur at only 0.5 to 1 mGy d⁻¹. The Canadian Nuclear Safety Commission (CNSC), using a traditional ecological risk approach, has also used a more conservative approach that what the DOE has adopted by establishing an Estimated No Effect Value for fish of 0.5 mGy d⁻¹ (Bird et al. *in press*).

Thus, agreement has not yet been reached as to what dose rate level is acceptable for biota. Perhaps most importantly, we do not have an adequate database to prove that the existing paradigm is true, particularly for chronic, low-level exposure scenarios, or in situations with multiple stressors. A lack of data exists for plant and animal dose rates to determine if regulatory compliance to these guidelines is being met on the SRS or on other DOE and U.S. Department of Defense complexes. Although exposures at many parts of the SRS have been well characterized, the relationship between exposure and absorbed dose is complex and robust methods for dose assessment are in need of development and testing.

- We have started an experiment in our Low Dose Rate Irradiation Facility using a transgenic fish (medaka) as our model organism. Fish will be chronically exposed to four irradiation levels: 350 mGy d⁻¹, 35 mGy d⁻¹, 3.5 mGy d⁻¹ and un-irradiated controls. Thus the design brackets DOE's recommended dose criterion of 10 mGy d⁻¹ for aquatic organisms. Molecular and population level effects will be examined as a function of dose rate.
- We have begun isolating microsatellite DNA loci from medaka. These loci will be used as markers of altered DNA repair in medaka and give a direct assessment of mutation rate by comparing genotypes of parents and offspring.
- We have also conducted experiments to directly determine mutation rates between parents and offspring of transgenic medaka using the model chemical mutagen ENU.

Genetic Changes in Response to Previous and Current Plant Operations

Principal Investigators: Travis C. Glenn, I. Lehr Brisbin Jr., Charles H. Jagoe, J Vaun McArthur, Christopher S. Romanek, Michael H. Smith, and Barbara Taylor

Alterations of genetic materials can occur in organisms living in contaminated environments, especially where radionuclides are one component of the total contaminant burden. The primary goal of this research is to test for genetic changes and other associated effects both in single-celled microbes and in complex multicellular organisms living in SRS environments contaminated with radionuclides and heavy metals. Specifically, the following are ongoing: (1) assess and

quantify the effects of previous and current plant operations on the genetic structure and function of sentinel species; (2) determine the level of organism exposure to contaminants; (3) determine the relationships between the effects in organisms and contaminant exposure, and (4) use this information to help DOE in its environmental compliance and remediation efforts. The most basic unit of change is the sequence of the base pairs within DNA strands; however, genetic damage and its effects can occur at scales that range from the gene, through the individual organism, to populations and communities. Thus, we use a variety of techniques to assess genetic damage and effects at several hierarchical scales. The principal techniques we use come from molecular, population and quantitative genetics, phylogenetics, population ecology, radioecology, ecotoxicology, and developmental biology. These techniques are used in both laboratory and field experiments as well as field surveys. The primary focus has been on flora and fauna from SRS sites, but we are increasing activities in the assessment of microbial communities (the subject of other summaries) and in the development of transgenic model systems. We also use organisms from elsewhere to provide control or reference sites and an appropriate ecological context to support the generality of our findings (e.g., some of the same biomarkers may be compared in ecologically equivalent species from the SRS and Chernobyl). Thus, our broader goal is to address applied problems with solutions that are based upon a solid theoretical and scientific basis.

We have completed several tasks during this last year:

- A manuscript was published that describes the use of whole transcriptome gene chips to identify candidate genes that respond to specific contaminants (metals were tested). This paper also demonstrates the proof of concept that by using a simple strategy, we could obtain the relevant promoters of the candidate genes to drive expression of an easily scored reporter gene with the same efficiency as the candidate gene in the genome of the model organism (SREL reprint #2639).
- A manuscript describing the long-term genetic impacts of pumping Savannah River water into SRS impoundments was accepted for publication: Staton, J. L., B. E. Taylor, N. V. Schizas, R. Wetzer, T. C. Glenn, and B. C. Coull. *In press*. Mitochondrial gene diversity of *Skistodiptomus mississippiensis* in impoundments of the Upper Coastal Plain near Aiken, South Carolina, USA. Archive fur Hydrobiologie.

- A manuscript was published describing hypervariable single-locus markers for a fish commonly found in the impoundments and streams of the SRS. These markers are now available for a variety of studies, including direct assessment of mutation rates (SREL reprint #2669).
- A manuscript was published describing the extremely limited amount of variation found in the mitochondrial DNA of American alligators. This adds to our body of evidence indicating no adverse effects of Site activities on the genetics of carnivores at the very top of the SRS food web (SREL reprint #2633).
- Transgenic lines of the model organism, *C. elegans*, have been constructed. One set of lines contains the promoter for metallothionein. These worms respond by increasing expression of Green Fluorescent Protein when exposed to heavy metals. Optimal conditions for measuring GFP expression and experiments to assess sensitivity of this model to the concentration of metals are underway. Additional lines have been constructed and are being characterized.

International Programs in Radioecology

Principal Investigators: Michael H. Smith, Charles H. Jagoe, Travis C. Glenn, and Domy C. Adriano

Studies at other sites offer opportunities to complement the long history of radioecology research at the SRS, and to study the distribution and behavior of radionuclides in different environments. Such comparative studies also offer the opportunity to evaluate the impacts of higher radiation doses than those presently occurring at SRS. For example, areas near the Chernobyl Nuclear Power Plant offer unique opportunities for important investigations that can (1) assist in planning and accident management in case of future releases, (2) assess the effectiveness of cleanup technologies, and (3) evaluate the risks associated with chronic exposure to radiation. SREL scientists have been involved with research at Chernobyl and other sites in the former Soviet Union since 1992 and have developed excellent working relationships with foreign scientists and administrators.

The establishment of the International Radioecology Laboratory (IRL) in Slavutych and Chernobyl, Ukraine is one concrete result of our efforts to strengthen working relationships with scientists in the former Soviet Union. The

IRL was established by two separate agreements: the Government to Government Agreement signed on 22 July 1998 by then Vice President Gore and Ukrainian President Kuchma and the Agreement between The University of Georgia and the Chernobyl Center for Nuclear Safety, Radioactive Waste, and Radioecology of 15 January 1999. Funds provided by DOE-SR were used to renovate laboratories and purchase research equipment and furnishings. The facility was dedicated in a ceremony in May 1999 by Deputy Secretary of Energy Glauthier and officially opened in March 2000. The laboratory allows researchers from SREL and other academic institutions in the former Soviet Union, Europe, and the United States to perform field studies in highly contaminated regions of the Chernobyl Zone and to analyze samples in a cost-efficient and coordinated manner. Activities at this laboratory facilitate interchanges of methods, ideas, and technologies from international experts working in the field of environmental radiation, toxicology, biology, and risk assessment. Studies conducted at the IRL will have high relevance for DOE in areas including radioecology, management of contaminated lands, health and ecological risk assessment, and evaluation of remediation technologies.

To date, focus has been the initiation of research programs in concert with scientists from The University of Georgia, University of South Carolina, and Texas Tech University, as well as securing funding for the continued operation of the IRL. One complete project tested the hypothesis that radioactive contamination altered genetic diversity and developmental stability in populations of small mammals in areas near Chernobyl using yellow-necked mice (*Apodemus flavicollis*) as a model species. This project resulted in a completed doctoral dissertation for a Ukrainian student working at the University of Georgia. An ongoing project examines radioactivity, genetic, and morphological variation in plants including *Typha latifolia*, *T. angustifolia* and *Betula verucosa* collected near Chernobyl as well as reference sites, including the US. A study of the distribution and effects of radionuclides on plants will be part of a doctoral dissertation of another Ukrainian student at UGA. A third project measures radioactivity in vertebrate and invertebrate animals from the Chernobyl area and the SRS to examine the frequency distributions of ¹³⁷Cs in populations. These frequency distributions are non-normal, as indicated by strong relationships between standard deviations and means. The shapes of radionuclide frequency distributions are critical to designing appropriate sampling strategies, and in developing

risk assessment models. Studies have also been done on radionuclide accumulation and effects in amphibians from contaminated wetlands near Chronobyl.

- A manuscript on radiocesium measurements in several species of amphibians collected near Chornobyl is in press. Frogs of the species *Rana terrestris* contained nearly twice as much radiocesium as *Rana esculenta* from the same area; this may reflect differences in diet between the species. Additional samples for genetic analyses have been collected in the past year.

RESEARCH SUPPORT PROGRAMS

Several SREL programs provide critical support to the research, outreach, and education missions of the Laboratory. These support programs include:

- National Environmental Research Park Program*
- Environmental Health & Safety Program*
- Distance Learning Program*
- Quality Assurance Program*
- Research Data Archive Activities*
- SREL Undergraduate & Graduate Education Programs*
- Environmental Outreach Program*
- DOE Research Set-Aside Areas*

National Environmental Research Park Program

I. Lehr Brisbin, Jr.

The Savannah River National Environmental Research Park (NERP) is a protected outdoor laboratory for long-term research projects to study the environmental impacts of human activities. Because public access to U.S. Department of Energy (DOE) land is limited, environmental research projects can be carried out on the lands of the Savannah River Site (SRS) with a minimum of interference. The NERP is not simply a site to conduct research, but also should have programs that address the following general objectives: (1) development of methods to assess and monitor the environmental impact of human activities both quantitatively and continually; (2) development of methods to estimate or predict the environmental response to proposed or ongoing site activities; and (3) demonstration of the impact of various activities on the environment and evaluation of methods to minimize adverse impacts. Pursuant to these objectives, it is necessary to supply basic data so that environmental decisions, standards, and monitoring programs can be developed upon a firm ecological and scientific base.

During the past year, although no specific funding was made available for site NERP activities, the SRS NERP Coordinator (I. L. Brisbin) made a number of presentations concerning NERP program goals and objectives at the SRS. Recently, Dr. Brisbin has also worked with an *ad hoc* committee to draft a resolution, supported by appropriate community leaders, that has been sent to the Secretary of Energy, calling for the SRS site boundaries to be maintained at their present location. This resolution could serve as the first step toward gaining the support of the Georgia and South Carolina legislative delegations for making a legislative designation of the SRS as a National Environmental Research Park.

Environmental Health and Safety Program

Donald R. Mosser and Vivian G. Dicks

The Savannah River Ecology Laboratory has completed its sixth year of operation under the work-smart safety and environmental standards that resulted from SREL's participation in U.S. Department of Energy's (DOE) Necessary and Sufficient process. These standards continue to address

the hazards associated with SREL operations by permitting a focused effort on the health and safety issues most pertinent to SREL operations.

The most significant change this year with regard to SREL's Environmental Health and Safety (EH&S) Program was the retirement of former EH&S Manager, Warren Safter in July, 2002. Donald Mosser, formerly SREL's Laboratory Safety Officer, was selected as SREL's new EH&S Manager (September 2002). Vivian Dicks was successfully recruited as SREL's new Laboratory Safety Officer (October 2002). SREL maintains a commitment of two full-time employee positions dedicated to the support of the SREL EH&S program.

In an effort to increase the efficiency and effectiveness of the EH&S Program, an emphasis continues to be placed on safety and environmental training of SREL personnel. New personnel safety and environmental orientation was presented to 52 individuals. Additionally, training was provided for Chemical Coordinators, hazardous waste workers, and radioactive sealed source users. WSRC provided Radiological Worker and radiation generating device training to SREL personnel as necessary. The SREL EH&S Manager attended Price Anderson Amendment Coordinator Training provided by the Department of Energy (December 2002).

SREL's internal computer network was used to provide targeted safety information to specific groups in the laboratory. Lessons learned and health and safety topics were distributed via e-mail throughout the year. Safety training literature was also made available in break rooms and hallway literature racks.

Facility inspections remain a cornerstone of the SREL Safety Program. SREL personnel conducted regularly scheduled facility inspections. In addition, SCDHEC conducted an inspection of SREL hazardous waste management areas. SREL also conducted assessments in the areas of chemical and radiological air emissions, community right-to-know, and the Georgia Right-to-Know law in compliance with state and federal requirements. Safety Services personnel reviewed and approved more than 300 chemical purchases.

Chemical disposal and waste minimization issues continued to be emphasized to increase efficiency and cost effectiveness. Waste minimization techniques such as source reduction and bench-top treatment continue to be incorporated into experimental protocols, reducing the burden associated with

waste disposal procedures while supporting SREL's pollution prevention efforts. In cooperation with WSRC Solid Waste Division, SREL successfully shipped approximately 550 pounds of excess hazardous laboratory chemicals and laboratory hazardous wastes to a hazardous waste disposal firm (May 2003).

Distance Learning Program

Laura Janecek and Marie Hamilton

The Savannah River Ecology Laboratory maintains a state-of-the-art Distance Learning (DL) facility that delivers two-way audio and visual transmissions via a T1 line. The two-classroom facility is part of the Georgia Statewide Academic and Medical Systems (GSAMS), a cooperative and collaborative distance education network in the state of Georgia with about 300 interactive audio and videoconference classrooms. This facility gives SREL the capability to communicate with other distance learning users throughout the country. SREL uses DL for classroom instruction for a Master's degree program, other graduate courses, outreach presentations, graduate student committee meetings, faculty meetings, and staff briefings. During the past year, the SREL Distance Learning Program continued to focus its efforts on programming related to SREL core programs in ecology and environmental science and provided almost 300 hours of programming to SREL and SRS personnel. The primary program for SREL is the interdisciplinary Master of Science degree in Environmental Toxicology, offered in cooperation with the UGA School of Pharmacy. This is the first degree offered by UGA through any distance learning site. Six students have completed all required coursework and are working on the research component of the degree, and one student has graduated from the program.

The SREL Outreach Program has been using DL technology to extend their programming because they can reach multiple classrooms as well as minimize travel and animal handling time by using this facility. Outreach personnel presented 18 lectures on various ecological topics to students in South Carolina and Georgia K-12 schools. Topics included:

- Reptiles and Amphibians of the Southeast
- This Multicolored World
- Life in Wetlands
- Animal Adaptations

- Alligators as Canaries
- How Oil has Made Us Dumber

Quality Assurance Program

Laura Janecek

SREL has continued to maintain a formal, U.S. Department of Energy (DOE)-approved Quality Assurance (QA) program. The program is devoted to assuring the continuing quality of SREL research. These SREL "Good Research Practices" highlight research concepts and context, research logistics, and the conduct of research and are available to all SREL personnel on the Lab's intranet web site. All new Laboratory research personnel are required to familiarize themselves with this material prior to beginning work at SREL.

Research Data Archive Activities

Laura Janecek and Debbie Reese

Responsible management of research data holdings plays an important role in preserving the SREL's corporate memory. Since 1989, SREL has been actively building a centralized repository of research data files and the associated "metadata" necessary to make these data fully accessible. The goals of SREL's Research Data Archive activity are to avoid the inadvertent loss of data and to use advanced electronic computer/communication technology, including the use of computer networks and the Internet, to provide access to important data as efficiently as possible. Inclusion of new and historical research information into the SREL data archives continued during FY03 and the Central Archive Data Repository now has information covering over 481 separate studies.

The web-based SREL data archive system that allows users to upload metadata information and actual data files directly from their office desktop computers worked well during FY03, facilitating participation by researchers. Anyone at SREL or on the SRS can search for data using this new web-based system, however decisions about releasing original data to third parties are retained by the principal investigators.

SREL Undergraduate and Graduate Education Program

J Vaun McArthur

The objective of the SREL Education Program is to promote professional development and enhance environmental awareness among undergraduate and graduate students through research participation and training programs with emphasis on conducting ecological research important to the Savannah River Site mission. Undergraduate and graduate student participants FY03 are listed in Table 1 (page 39).

The SREL Education Program has averaged 20 undergraduate students per year since 1968. These students, from over 250 different colleges and universities, have been co-authors on 135+ peer reviewed research publications; more than 150 of these students have gone on to pursue careers in science. The Undergraduate-Research Experience for Undergraduates, funded by the National Science Foundation, sponsored 12 students this year. In addition, we sponsored four students funded by NOAA, one student funded by SREL, and two funded by South Carolina State University.

Since 1967, an average of six students a year have completed graduate studies at SREL and over 290 dissertations and theses have been written. During FY03 seven students completed their degree requirements (three M.S. and four Ph.D.). Since 1985, our graduate students have won over 175 awards from regional, national, and international competitions at numerous professional societies and foundations. During the past year, our graduate students continued to compete successfully for various national and regional awards. Some of these are listed in the section on Special Accomplishments (page 46).

SREL Graduate Students Completing Degree Requirements:

Sue Humphries M.S.–University of South Carolina, Columbia–Travis Glenn

Jessica Hutchison M.S.–University of Georgia, Athens–John Seaman

Pat Shaw-Allen Ph.D. –University of Georgia, Athens–Charles Jagoe

Robert Thomas Ph.D. –University of Georgia, Athens–Christopher Romanek

Ria Tsaliagos M.S.–University of Georgia, Athens–J. Whitfield

Gibbons

Momin Uddin Ph.D.–University of Georgia, Athens–Gary Mills

Wei Wei Zhong Ph.D.–University of Georgia, Athens–Chuanlun Zhang

Environmental Outreach Program

J. Whitfield Gibbons

The Savannah River Ecology Laboratory's missions of research, outreach, and education have resulted in a respected resource in the greater Aiken-Augusta area. The intellectual independence of academic research assures the local community of objective research on the impacts of site operations on ecosystems of the SRS and the region. In addition, the outreach efforts of SREL to the general community have been successful from preschoolers to the business community.

SREL uses information from its own research efforts to educate the public locally, regionally, and nationally. The environmental commitments of SREL extend beyond the lab, the SRS, and even the larger local area. Issues as diverse as amphibian and reptile population declines, potential responses of organisms to local contamination, the distribution and abundance of sensitive species, monitored natural attenuation programs, and the dispersal of organisms from radioactively or chemically contaminated sites all are important beyond SREL.

The Outreach Program is designed to enhance SREL's overall mission of acquiring and communicating environmental knowledge and addresses the U.S. Department of Energy's (DOE) current focus on environmental issues. Some of the ways this is accomplished include the following:

- School groups enjoy field trips to the Laboratory's Conference Center and speakers from SREL go to schools, presenting programs on conservation, the process of science, and environmental stewardship.
- Over 350 4th and 5th grade students at two Aiken County elementary schools participated in 5 two-hour hands-on science workshops and a daylong field trip. Scientific inquiry and process skills were stressed; students worked in groups, conducted experiments, and recorded and analyzed data.

TABLE 1. SREL Undergraduate and Graduate Student Program Participants*UNDERGRADUATE RESEARCH PARTICIPATION PROGRAM*

| Student | Academic Institution | Faculty Advisor |
|-------------------|---------------------------------------|-----------------------------|
| William Drayton | Benedict College, SC | J Vaun McArthur |
| Gerrell Grant | South Carolina State University, SC | Gary Mills/Tracy Punshon |
| Jill Harris | Dartmouth College, NH | Steve Harper |
| Janet Hart | Brigham Young University, UT | J Vaun McArthur |
| Cori Holladay | Anderson College, SC | Beverly Collins |
| Chalita Johnson | Johnson C. Smith University, NC | Travis Glenn |
| Kelly Jones | The College of Charleston, SC | Kenneth McLeod |
| Kent Langerlan | State University of New York, Geneseo | Christopher Romanek |
| Meghan Langley | Centre College, Danville, KY | Lee Newman |
| Benjamin Lawrence | Ohio Wesleyan University, OH | J. Whitfield Gibbons |
| Kevin McCray | South Carolina State University, SC | Gary Mills/Tracy Punshon |
| Kevin Messenger | North Carolina State University, NC | Machelle Wilson/Robert Reed |
| Kimberly Munkers | Presbyterian College, SC | I Lehr Brisbin/Karen Gaines |
| Tanjenique Paulin | Benedict College, SC | Charles Jagoe |
| Maureen Peters | Ohio University, OH | Travis Glenn |
| Yoana Rosales | Chicago State University, IL | Charles Jagoe |
| Rebecca Rudicell | Warren Wilson College, NC | Paul Bertsch/Heather Dion |
| Adam Smith | Bowling Green State University, OH | Steve Harper |
| Siobhan Watson | Vassar College, NY | Thomas Hinton/Bonjun Koo |

GRADUATE RESEARCH PARTICIPATION PROGRAM

| Student | Degree | Institution | Faculty Advisor |
|-----------------------|---------------|--|------------------------|
| Kimberly Andrews | M.S. | University of Georgia, Athens | J. Whitfield Gibbons |
| Elizabeth Burgess | M.S. | University of Georgia, Athens | J Vaun McArthur |
| *Rebecca Cerajewski | M.S. | University of Georgia, Athens | Christopher Romanek |
| Erin Clark | M.S. | University of Georgia, Athens | J. Whitfield Gibbons |
| Sara Drake | M.S. | University of Georgia, Athens | Beverly Collins |
| Luke Fedewa | M.S. | University of Georgia, Athens | J. Whitfield Gibbons |
| Bobbi Fokidis | Ph.D. | Arkansas State University, Jonesboro | Travis Glenn |
| Xavier Glaudas | M.S. | University of Georgia, Athens | J. Whitfield Gibbons |
| Susanne Hauswaldt | Ph.D. | University of South Carolina, Columbia | Travis Glenn |
| Sue Humphries | M.S. | University of South Carolina, Columbia | Travis Glenn |
| Jessica Hutchinson | M.S. | University of Georgia, Athens | John Seaman |
| Virginia Jin | Ph.D. | University of Georgia, Athens | Rebecca Sharitz |
| *Lara Katers | M.S. | Colorado State University, Fort Collins | Thomas Hinton |
| Yong Jin Lee | Ph.D. | University of Georgia, Athens | Christopher Romanek |
| *Jackie Litzgus | Ph.D. | University of South Carolina, Columbia | William Hopkins |
| Audrey Majeske | M.S. | University of Georgia, Athens | Charles Jagoe |
| Liberty Moore | M.S. | University of Georgia, Athens | I. Lehr Brisbin |
| John Mulhouse | M.S. | University of Georgia, Athens | Rebecca Sharitz |
| *Elizabeth Richardson | M.S. | University of Georgia, Athens | J Vaun McArthur |
| Steven Schaff | Ph.D. | University of Georgia, Athens | Kenneth McLeod |
| Pat Shaw-Allen | Ph.D. | University of Georgia, Athens | Charles Jagoe |
| *Sarah Shuler | M.S. | University of Georgia, Athens | Charles Jagoe |
| Julian Singer | M.S. | University of Georgia, Athens | John Seaman |
| Amy Squires | M.S. | University of Georgia, Athens | Rebecca Sharitz |
| Robert Thomas | Ph.D. | University of Georgia, Athens | Christopher Romanek |
| Ria Tsaliagos | M.S. | University of Georgia, Athens | J. Whitfield Gibbons |
| Olga Tsusko | Ph.D. | University of Georgia, Athens | Michael Smith |
| Susan Turner | Ph.D. | University of Georgia, Athens | Rebecca Sharitz |
| Momin Uddin | Ph.D. | University of Georgia, Athens | Gary Mills |
| Laura Uhrich | M.S. | University of Georgia, Athens | Rebecca Sharitz |
| Jason Unrine | Ph.D. | University of Georgia, Athens | Charles Jagoe |
| *Judith Unterkoefer | Ph.D. | University of Agricultural Sciences, Austria | Domy Adriano |
| *Chelsea Ward | Ph.D. | Auburn University, AL | Justin Congdon |
| Lucas Wilkinson | M.S. | University of Georgia, Athens | J. Whitfield Gibbons |
| Jamie Williams | M.S. | University of Georgia, Athens | Barbara Taylor |
| Christopher Winne | Ph.D. | University of Georgia, Athens | J. Whitfield Gibbons |
| Cameron Young | Ph.D. | University of Georgia, Athens | J. Whitfield Gibbons |
| *Caralyn Zehnder | Ph.D. | University of Georgia, Athens | William Hopkins |
| Wei Wei Zhong | Ph.D. | University of Georgia, Athens | Chuanlun Zhang |
| Qi Ye | Ph.D. | University of Georgia, Athens | Chuanlun Zhang |

*Short-term students – did not complete degree.

- Teachers are trained in methods of teaching ecology during workshops and leave with materials produced by the Outreach staff.
- Increased demand for Outreach speakers has required greater use of the Distance Learning Facility, reaching a total of 1,472 additional students in K-12.
- An internal laboratory newsletter, *The GrapeVine*, is distributed electronically, 12 times per year.
- During the past year, SREL scheduled 329 talks, 9 tours, 29 exhibits, and 49 workshops, for a total of 119,400 people reached. Topics for these presentations included biodiversity, the process of science, animal adaptation, plants and wetlands, chemistry and environmental science, local ecosystems and conservation, classification, and careers in ecology and research. The education functions of the lab have been consolidated within the outreach group.
- The Outreach program has received recognition from the Council for the Advancement and Support of Education and individuals within the program have been honored by the states of Georgia and South Carolina as well as by various local school districts and national organizations for their outreach efforts.

Outreach programs include “Ecotalk,” an opportunity for students to have nature brought into their classroom for a face-to-face lesson on a variety of live animals found in local habitats. These presentations, offered in schools, emphasize hands-on scientific learning using activities in the environmental sciences. “Ecologist for a Day” visits allow students to spend the day in the field gaining “hands-on” knowledge of the plants and animals of the unique Upper Three Runs Creek area. Participants get an opportunity to work with SREL researchers catching, marking, and measuring various species of reptiles, amphibians, small mammals, and invertebrates. In addition, the Outreach Program offers tours of SREL facilities and surrounding field sites, as well as exhibits and workshops for the general public.

During the past year SREL developed a new hands-on “research-to-classroom” science program for elementary school students. With funding from The Christensen Fund, SREL presented five two-hour workshops to every 4th and 5th grade class at East Aiken and Greendale Elementary schools in Aiken County, SC. In each two-hour classroom session, SREL staff showcased one or two SREL researchers conducting studies in subject areas related to the topic of the day, and

students learned about on-going research by scientists working in their community. Students then performed hands-on activities that reinforced the content, as well as scientific inquiry and process skills. All activities were linked in some way to local habitats, particularly isolated wetlands and streams of high ecological value, as well as to South Carolina and national science standards. A variety of techniques were used to ensure that all programs included as many of the “five senses” as possible, to accommodate different learning styles among students and to reinforce to students and teachers that science can be fun. At the conclusion of the program, all students participated in a daylong field trip and acted as “junior scientists” by using the skills taught in the classroom in an outdoor setting. SREL is seeking additional funding to continue this program in future years.

Continuing with an initiative begun in 2001, activities with an emphasis on environmental sciences and the process of science were implemented in schools, scout camps, home-school groups, and teacher workshop environments. Hands-on activities covering topics as diverse as the use of genetics in forensics, groundwater contamination and bio-accumulation, phytoremediation, cleaning up oil spills, the chemistry of lipids, chemical defenses and attractants in insects, waste water treatment, chemical concentrations, acids and bases, and the ecology and chemistry of birds have been developed. Despite the advanced nature of some topics, SREL staff have found ways to present them in engaging ways even to very young audiences. SREL plans to expand upon this program base in the years to come as the process of science, research in environmental chemistry, and education about conservation are combined into a unified set of environmental science activities.

Thousands of copies of educational products and materials are distributed nationwide to schools, organizations, and the general public. Educational materials include two six-foot-long full-color posters describing the importance of wetlands to reptiles and amphibians, along with teachers’ guides, and the Outdoor Classroom Planning Guide. The full-color brochure *Snakes of Georgia and South Carolina* has proved to be an extremely successful educational product that reflects positively on DOE and the SRS. In the five years since its publication, its popularity has grown and necessitated four printings; demand for the book has grown as additional sponsors support and distribute it to their constituencies. The book has been placed at no charge in every public library

in Georgia and South Carolina and is also widely distributed at no cost to hospital emergency rooms, veterinary clinics, ambulance services, classrooms, scout leaders, and to various other organizations such as the Boys and Girls Clubs in Aiken and Augusta. Articles referencing the book have appeared in numerous newspapers and magazines including publications in Florida and Texas.

New Outreach products produced this year included a poster on amphibians and reptiles, produced in support of Partners in Amphibian and Reptile Conservation (PARC) with funding from the National Fish and Wildlife Foundation; a six-page full-color fact sheet on the American alligator; and a flier on the eastern indigo snake, funded by the U.S. Department of Interior. Other Outreach publications include fliers on *Carnivorous Plants and Their Habitats* and *An Amphibian's Eye View of Wetlands*; a children's comic book entitled *Stepping into Ecology: the Ecological Adventures of Mud E. Boot*; a flier on *Is it a Water Moccasin?*; and an emergency services calendar that depicts animals, plants, and habitats of the SRS, produced in cooperation with Westinghouse Savannah River Company. As part of a new outreach initiative in chemistry and environmental science, a large sticker with the slogan "Chemistry—it's all about the nature of things" was produced and is given to all students who participate in the classroom and workshop programs in this new subject area. All of these products have been extremely popular and thousands of copies have been distributed during the past year.

The Outreach Program also continues to produce and distribute various other publications, including *Outdoor Classroom Planning Guide*, *Biodiversity: Prospect & Promise for the Savannah River Site*, and *The National Environmental Research Park at Savannah River Site: Serving an Essential Mission for 25 Years*. The *Outdoor Classroom Planning Guide* gives instructions for setting up a variety of outdoor classroom stations and outlines activities and investigations that teachers can use to guide students through hands-on learning experiences in natural settings. The biodiversity brochure highlights the Site's vast natural resources, explains biodiversity in general, and defines its various types, such as genetic diversity. The National Environmental Research Park (NERP) brochure highlights 25 years of research associated with the NERP program at the Savannah River Site. Plant researchers have been instrumental in producing new plant fliers, including *Wild Orchids of South*

Carolina, *Carolina Milkweeds*, and *Trilliums of South Carolina*. Full-color fact sheets and research "snapshots" on a wide variety of research topics are produced and distributed as well.

The public relations component of the Outreach Program includes the distribution of news releases on a variety of topics to selected media affiliates, officials of DOE, and The University of Georgia. Included among these has been coverage of SREL research by CNN, U.S. News and World Report, New York Times, Associated Press, BioScience, Earth Magazine, National Wildlife Magazine, National Public Radio, Our World, Atlanta Journal & Constitution, Weekly Reader, Los Angeles Times, National Geographic, Audubon, Smithsonian Magazine, The Washington Post, Fox News, and more. The Public Relations office screens most inquiries from the press, directing reporters to the most helpful researchers for their stories. In addition, SREL initiates press contacts, postings on Newswise, and regular submissions to popular magazines, resulting in stories and new contacts with the media including stories in *Reptile Life*, *The World & I*, and *Environmental News Network*. Regular mentions in UGA publications are also sought.

Outreach also has promoted various research projects through coverage in local and national media and has worked to enhance the laboratory's internal communications. Participation in the CSRA Environmental Consortium has provided the opportunity to showcase SREL at Augusta's Fort Discovery Science Museum and also has provided an opportunity for speakers from the Lab to address groups at Fort Discovery.

DOE Research Set-Aside Areas

Charles E. Davis

The Savannah River Site (SRS) is a National Environmental Research Park (NERP) and its large land area and controlled public access provide a diverse and protected outdoor laboratory where researchers study the environmental impacts of the SRS's industrial and forest management operations. Because these studies are usually long-term, they require relatively undisturbed areas as "control" sites where reference, baseline data can be obtained. Known as Research Set-Aside Areas, these reference sites have been withdrawn from the SRS's commercial forest and set aside by the Department of

Energy (DOE) primarily for non-manipulative ecological research and educational outreach activities. These areas also serve as “reserve” areas that represent excellent examples of both the typical and unique plant communities indigenous to the SRS while providing critical habitat for the Site’s threatened, endangered, or sensitive (TES) flora and fauna. Inclusion in the Set-Aside Program ensures that these areas will be preserved and protected, aid in the maintenance of a high degree of biological diversity on the SRS, and will enable DOE-Savannah River (SR) to meet the objectives of the NERP Program. Currently, there are 30 Set-Aside Areas on the SRS that collectively account for approximately 14,100 acres (5,706 ha), or 7 % of the Site. Individually, they range in size from 10 acres (4.05 ha) to 7,400 acres (2,995 ha), and are located in 43 of the Site’s 89 timber resource compartments. There are approximately 270 miles (168 km) of posted boundary line associated with these Set-Aside Areas.

SREL’s Set-Aside Program

The DOE Set-Aside Program is administered by SREL and is overseen by a six-member Set-Aside Task Group composed of natural resource experts from SREL, the South Carolina Department of Natural Resources (SCDNR), the United States Forest Service-Savannah River (USFS-SR), Westinghouse Savannah River Company (WSRC), and DOE-SR. In 1993, a Set-Aside Protection and Management Plan for the SRS was written by SREL and the USFS-SR to provide general guidance to SREL and the Set-Aside Task Group to manage the Set-Aside Areas. To date, this plan has been successfully implemented by SREL primarily because the Task Group has been able to resolve land use conflicts and because the SRS’s Site-Use Permitting System has been effective in preventing impacts to Set-Asides. The Set-Aside Areas are permitted under SREL’s Site-Use Permits SU-79-74-R and SU-89-58-R, and any potential land use or research conflict with a Set-Aside Area is normally addressed and resolved using this system.

Maintenance of the Set-Aside Areas

Periodic inspections of Set-Aside boundary postings continue to be conducted by SREL where potential land-use conflicts are anticipated. SREL and the USFS-SR continue to verify/update Set-Aside boundary lines that are concordant with the boundaries of prescribed forest stand treatments. Based on these boundary line updates, SREL routinely maintains and updates a Set-Aside GIS boundary data layer, which is made

available as a working coverage to USFS-SR timber and GIS personnel for timber stand updating. To date, a significant portion of the original version of the boundary layer coverage has been modified as the result of the USFS-SR and SREL GPSing timber sale and Set-Aside boundaries. A total of 10 Set-Aside Areas have been GPSed and a significant portion of the E. P. Odum Wetland Set-Aside, as well as others, have been completed. An updated version of the Set-Aside GIS boundary data layer was to be released to the general site in FY03 but this was not accomplished; however, the metadata for this coverage were updated and released. In addition, the USFS-SR’s seasonal prescribed burning program is coordinated with SREL for Set-Aside protection and permanent fire lines have been established around a number of Set-Aside Areas to reduce this coordination effort. However, this fire line construction continues to be re-evaluated and currently is on hold as a result of the USFS-SR using larger than anticipated equipment to plow fire lines. Also, SREL and the USFS-SR continually monitor any potential pine beetle problems in Set-Aside Areas and also coordinate for nuisance animal control.

Management of the Research Set-Aside Areas

SREL is directed to prepare stewardship management plans for each of the 30 Set-Aside Areas, and SREL’s Set-Aside Research Coordinator is responsible for developing, writing, and implementing these plans. Because of this responsibility, this person continues to serve as SREL’s Interdisciplinary (ID) Team representative to the USFS-SR’s timber compartment prescription review process where SREL has input to the development of natural resource management plans for the commercial forest. This position includes membership on watershed core teams and includes providing written observations and recommendations for each watershed compartment. This input enables the USFS-SR and SREL to verify Set-Aside and timber stand boundary line concordance with GIS coverages, update TES population surveys conducted in Set-Aside Areas, and address potential conflicts with forestry activities adjacent to Set-Asides and SREL research areas. USFS-SR timber management plans continued to focus on developing management prescriptions for the Site’s sub-watersheds, and these plans may include restoring historical plant communities in addition to the traditional pine silvicultural prescriptions and wildlife habitat improvement treatments for the Red-cockaded Woodpecker. Because these treatments to the commercial forest are prescribed over a

ten-year period, it is logistically preferred that management plans be developed for Set-Aside Areas in those timber compartments scheduled for prescription renewal so that prescribed treatments to the commercial forest and the Set-Aside Areas can occur simultaneously.

These 10 year management plans for the Set-Aside are generally developed by a core team of individuals from various Site organizations and, when necessary, researchers with individual expertise or with a long-term research interest in a Set-Aside may be requested to participate as core team members. Each Set-Aside Area management plan has its own assumptions, guidelines, and desired future conditions and each Area's plan addresses both general long-term management objectives and specific management strategies that dictate treatments to the Area's vegetation. Additional management considerations are addressed, including TES flora and fauna, boundary line and road maintenance, fire suppression, and clean-up of research sites. As these natural resource plans are formulated, SREL and USFS-SR negotiate possible administrative land exchanges (trades in some cases) so that unique and under-represented habitats can be expanded or included in the Set-Aside Program. Unfortunately, in reality, these 10-year plans have been thrown off schedule because the USFS-SR has moved to developing prescriptions for multiple sub-watersheds on the SRS during any one fiscal year. Consequently, SREL no longer is able to maintain a schedule for developing management plans for Set-Asides located in so many compartments.

During the past year, SREL worked on developing a management plan for the Rainbow Bay Set-Aside, which included GPSing the drift fence and locating abandoned research materials. Also stand boundaries were laid out and flagged for a thinning treatment to be conducted under the USFS-SR's Small Sales Site Use Permit SU-03-01-E. This Set-Aside plan was not completed during FY03. The 30-acre pine thinning treatments in the Flamingo Bay Set-Aside were marked this FY to begin implementation of this Set-Aside's management plan and timber is scheduled to be removed in the fall of FY04. SREL flagged beneficial wildlife and hardwood species for protection during the cutting and removal. In FY03, discussions continued as part of the conservation easement agreement between Chem Nuclear and DOE, with the intention that USFS-SR and SREL would work together to develop a fire management plan for the DOE portion of Craig Pond even though future vegetation management options have been

compromised due to the wildfires in FY02. As part of these options, the USFS-SR determined that salvage operations in this Set-Aside will not be recommended. Ongoing rehabilitation efforts continue for fire lines that were put in to control the fires. Also, the burning of Craig Pond and the fact that many of the Carolina Bay Set-Asides have remained dry this FY due to prolonged drought sparked interest among some SREL researchers to burn Steel Creek Bay and Ellenton Bay. Therefore, under Site Use Permit SU-02-39-R, the USFS-SR, SREL, and SCE&G worked together this year to develop a prescribed burn plan for Ellenton and Steel Creek Bays if weather conditions and research needs present an opportunity to burn in the future. A committee (ACWA) comprised of both Aiken city and County planners, SREL, and DHEC, was formed this FY to develop protective measures for preserving the integrity of the Upper Three Runs Creek watershed in Aiken County. Hopefully, this will lead to planned and environmentally sensitive development in the upper most reaches of the UTRC watershed. The 2-acre section of the Old UGA Lab Set-Aside that was turned over to the USFS-SR in FY02 to manage for sand pine regeneration was cut this year; however this section still remained as part of the Set-Aside. Finally, as a result of DOE security measures related to 9-11, SREL continues to lose convenient access to five Set-Asides.

Also this year, USFS-SR and the Set-Aside Research Coordinator began working together to GPS and Site Use the location of superior or record hardwood seed trees on the SRS that are currently being used for seed sources in hardwood regeneration projects. Also, due to high rainfall events late this FY, the Risher Pond dam failed and SREL is determining the impacts to future research; the Risher Pond Set-Aside has long been a site for obtaining control animals for research studies.

Research in Set-Aside Areas

Researchers from SREL continued numerous long-term plant and animal studies in Set-Asides. These studies include: aquatic macro-invertebrate and organic detritus studies in Upper Three Runs Creek; a genetics study examining variation over a small mammal species' range; daily amphibian population monitoring at Rainbow Bay; and the continued use of animals from Risher Pond and Ginger's Bay as controls for D-Area mercury and heavy metals studies. Monitoring studies of turtle nesting and predation, studies of the reproductive behavior of frogs and salamanders, and rare

plants diversity studies were conducted in Carolina Bay Set-Asides and their results were published this year. In addition, these bay Set-Asides continue to be used as proxies in studies of the hydrology of man-made catchment basins; these studies continue to support efforts to remediate such basins. Plant studies continue to examine the physiology of scrub oak species in the sandhills and resource heterogeneity of plants in old-fields.

Other studies that were initiated or continued this fiscal year in Set-Asides included: trophic transfer of heavy metals and sediment contamination using Set-Asides as control sites; dispersal of amphibians from an ephemeral wetland; and the use of Set-Asides for a studying soil nitrogen and plant organic uptake. In addition, a study was initiated examining the effects of forest management practices on seed production and seedling recruitment. The Sandhills Set-Aside is being used to study the temporal changes in a sandhills herpetofaunal community. Mercury studies continue as well using Carolina bay Set-Asides in ecological and health risk assessments looking at impacts on the endangered Wood Stork and raccoons, a game species hunted on Crackerneck.

Groups other than SREL also use the Set-Aside Areas. SRTC continued to use organisms collected in Set-Asides as "controls" to test methods of evaluating remediation and restoration actions as well as the development of terrestrial bio-assessment protocols at DOE sites. Archaeologists with the USC-Savannah River Archaeologist Research Program continued to conduct archaeological investigations around Set-Aside Carolina bays. In cooperative efforts, SREL and USFS-SR researchers continue to study coarse woody debris decomposition, softmast production in bottomland hardwood forests, and the role of fleshy fruit production, consumption, and dispersal on promoting biological diversity. Data from long-term studies in Set-Aside Carolina bays continues to be used to help manage and protect these unique wetlands and for providing technical information for formulating the State's regulatory policy towards isolated depressions. Because these wetlands have recently lost Corp of Engineer jurisdictional protection., a tour was conducted this year on the SRS for those state agencies responsible for protecting these wetland areas and Bay Set-Asides were the focal point used in educating this tour group about their ecological value.

FY03 SREL documents, publications, theses, and dissertations that used DOE Set-Aside Areas

Twenty-three documents were published this year that used habitats or organisms associated with Set-Aside Areas. Based on SREL's list of publications, 13 of the Set-Aside Areas had recent published research associated with them this fiscal year. Two publications referenced the Set-Aside Areas collectively.

Recent SREL documents, scientific publications, theses, and dissertations that used DOE Set-Aside Areas during FY03 included:

- Boone, M. D., D. E. Scott and P. H. Niewiarowski. 2002. Effects of hatching time for larval ambystomatid salamanders. *Copeia* 2:511-517.
- Brant, H. A., C. H. Jagoe, J. W. Snodgrass, A. L. Bryan, Jr. and J. C. Gariboldi. 2002. Potential risk to wood storks (*Mycteria americana*) from mercury in Carolina Bay fish. *Environmental Pollution* 120:405-413.
- Brisbin, I. L., Jr., M. H. Smith and J. D. Peles. 2002. Contributions of radioecology to the development of some modern concepts of ecotoxicology: from ecological half-life to monitored natural attenuation. *Radioprotection-Colloques* 37:C1-179-C1-183.
- DeVault, T. L. and O. E. Rhodes, Jr. 2002. Identification of vertebrate scavengers of small mammal carcasses in a forested landscape. *Acta Theriologica* 47:185-192
- Dietz-Brantley, S. E., B. E. Taylor, D. P. Batzer and A. E. DeBiase. 2002. Invertebrates that aestivate in dry basins of Carolina Bay Wetlands. *Wetlands* 22:767-775.
- Edwards, A. L. and R. R. Sharitz. 2003. Clonal diversity in two rare perennial plants: *Sagittaria isoetiformis* and *Sagittaria teres* (Alismataceae). *International Journal of Plant Sciences* 164:181-188.
- Gaines, K. E., C. S. Romanek, C. S. Boring, C. G. Lord, M. Gochfeld and J. Burger. 2002. Using raccoons as an indicator species for metal accumulation across trophic levels: A stable isotope approach. *Journal of Wildlife Management* 66:811-821.
- Ganser, L. R., W. A. Hopkins, L. O'Neil, S. Hasse, J. H. Roe and D. M. Sever. 2003. Liver histopathology of the southern watersnake, *Nerodia fasciata fasciata*, following chronic exposure to trace element-contaminated prey from a coal ash disposal site. *Journal of Herpetology* 37:219-226.

- Hopkins, W. A., C. P. Tatara, H. A. Brant and C. H. Jagoe. 2003. Relationships between mercury body concentrations, standard metabolic rate, and body mass in eastern mosquitofish (*Gambusia holbrooki*) from three experimental populations. *Environmental Toxicology and Chemistry* 22:586-590.
- Jackson, B. P., W. A. Hopkins and J. Baionno. 2003. Laser ablation-ICP-MS analysis of dissected tissue: a conservation-minded approach to assessing contaminant exposure. *Environmental Science & Technology* 37:2511-2515.
- Kolka, R. K., C. C. Trettin, E. A. Nelson, C. D. Barton and D. E. Fletcher. 2003. Application of the EPA wetland research program approach to a floodplain wetland restoration assessment. *Journal of Environmental Monitoring & Restoration* 1:37-51.
- Krenz, J. D. and P. A. Verrell. 2002. Integrity in the midst of sympatry: does sexual incompatibility facilitate the coexistence of metamorphic and paedomorphic mole salamanders (*Ambystoma talpoideum*)? *The Zoological Society of London* 258:435-440.
- Lord, C. G., K. F. Gaines, C. S. Boring, I. L. Brisbin, Jr., M. Gochfeld and J. Burger. 2002. Raccoon (*Procyon lotor*) as a bioindicator of mercury contamination at the U.S. Department of Energy's Savannah River Site. *Archives of Environmental Contamination and Toxicology* 43:356-363.
- Mills, G. L., J. V. McArthur and C. P. Wolfe. 2003. Lipid composition of suspended particulate matter (SPM) in a southeastern blackwater stream. *Water Research* 37:1783-1793.
- Mills, M.S. 2002. Ecology and Life History of the Brown Water Snake, *Nerodia taxispilota*. Dissertation, University of Georgia, Athens, Georgia.
- Plague, G. R. and J. H. Larson. 2002. Analysis of an apparent genetic cline in the stonefly *Pteronarcys scotti* (Plecoptera: Pteronarcyidae). *Journal of Entomological Science* 37:278-280.
- Punshon, T., P. M. Bertsch, A. Lanzirrotti, K. W. McLeod and J. Burger. 2003. Geochemical signature of contaminated sediment remobilization revealed by spatially resolved X-ray microanalysis of annual rings of *Salix nigra*. *Environmental Science & Technology* 37:1766-1774.
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SPECIAL ACCOMPLISHMENTS OF FACULTY, STAFF, AND ADMINISTRATION

Honors and Awards

Karen Gaines received the University of South Carolina's 2003 Norman J. Arnold School of Public Health Doctoral Achievement Award at the June commencement ceremonies for her dissertation, titled *Spatial Modeling of Receptor Species for Ecological Risk Assessment Activities on the Department of Energy's Savannah River Site*. Karen is a graduate student and research coordinator working with the ETRRA research group and **Dr. I. Lehr Brisbin's** research program.

Dr. Christopher Romanek published two papers in prestigious journals during the past year: one in *Science* and one in *Proceedings of the National Academy of Sciences USA* (see publications section on page 53).

Two new faculty members joined SREL. **Dr. Chuanlun Zhang**, who specializes in geomicrobiology and environmental microbiology, and **Dr. Andrew Neal**, who studies metal metabolism by bacteria. Both joined SREL's AACES research group.

Drs. Christopher Romanek, Andrew Neal, and Chuanlun Zhang of SREL, along with Jurgen Wiegel and Douglas Crowe of UGA, received a \$1M three-year grant from the National Science Foundation for their project *Collaborative Research: Kamchatka, a Geothermal Microbial Observatory*.

Virginia Jin, a Ph.D. candidate at SREL, co-edited the book *Ecology of Korea*, a 406-page summary of recent environmental research in Korea. The book, intended to introduce the current status of ecological studies in Korea to the international ecological community, covers five major scientific disciplines. Virginia is a student of **Dr. Rebecca Sharitz**.

Research publications by **Drs. Christopher Romanek and Robert Reed** were featured in the zoology section of the 2003 *Encyclopedia Britannica Year Book*, which reports on outstanding scientific research conducted anywhere in the world during the previous year.

Dr. William Hopkins was invited to be a member of the International Steering Committee for the International Summit on Global Amphibian Decline, sponsored by four continental chapters of the Society of Environmental Toxicology and Chemistry. The committee has 15 members from six countries.

John Willson received a three-year National Science Foundation graduate research fellowship for his proposal to study cottonmouth snakes on the barrier islands of South Carolina. Willson will attend UGA, where he will be a student of **Dr. J. Whitfield Gibbons**.

Dr. Thomas Hinton, with Dr. Dan Kaplan of SRTC, received a ranking of Excellent/Outstanding in November 2002 from a DOE complex-wide review board for their research project on the *in situ* remediation of ¹³⁷Cs-contaminated wetlands using illite.

Jessica Hutchison won First Place and a \$500 prize in the graduate student presentation competition at the national meeting of the Agronomy Society of America, in November 2002. Jessica is a graduate student of **Dr. John Seaman**.

Dr. Domy Adriano, with Walter Wenzel and Judith Unterkoefer, has received an Austrian patent for a process that uses both phytoremediation and *in situ* technologies to remove contaminants from soil. A U.S. patent application is pending.

Dr. Heather Dion was selected to receive a "Women's International Science Collaboration Program" travel grant. This award, funded by the American Association for the Advancement of Science and supported by the National Science Foundation, will allow Heather to travel to the Ukraine to conduct research at the site of the Chernobyl nuclear accident.

Steve Schaff, a graduate student advised by **Dr. Ken McLeod**, was elected President of the Coastal Plains Chapter of the Society for Ecological Restoration. He will serve a two-year term.

Dr. J Vaun McArthur obtained a contract from Academic Press to write a text book on microbial ecology.

Graduate students **Heather Brant**, **Angel Wall**, and **Jason Unrine**, along with SREL faculty member **Dr. Charles Jagoe**, received the "Best Poster" award during the Interdisciplinary Toxicology Program Faculty, Staff and Student Retreat held in Athens in March 2003. Heather and Jason are students of **Dr. Jagoe**; Angel is a student of **Dr. John Seaman**.

Dr. Paul Bertsch co-chaired a DOE Office of Science workshop titled "Opportunities for studies of contaminant transport in fluvial systems at the Tims Branch-Steeds Pond System, Savannah River Site." Held at the SREL conference center, the workshop was organized by SRTC, with assistance from SREL. Participants from across the country attended; several SREL researchers gave presentations.

Ria Tsaliagos, **Luke Wilkinson**, and **Susan Turner** received "Honorable Mention" awards for their presentations at the 2003 Institute of Ecology Graduate Student Symposium.

Dr. Rebecca Sharitz and researcher **David Scott** were nominated for the 2002 National Wetlands Award co-sponsored by the Environmental Law Institute, EPA, NRSC, FWS, USFS, and NOAA/NMFS.

Dr. Chuanlun Zhang received an American Geophysical Union "Certificate of Appreciation" for contributions in support of earth and space sciences education.

Dr. Paul Bertsch was elected Division S-2 Chair-Elect of the Soil Science Society of America. He also was appointed to the Advanced Photon Source Scientific Advisory Committee and the Advisory Board of Advances in Agronomy.

Christopher Winne was awarded a Grant-in-Aid of Research from the scientific research society Sigma Xi to support his graduate research on thermal performance traits of water snakes. Chris is a student of **Dr. Whit Gibbons**.

Drs. Andrew Neal and **Travis Glenn** received new faculty research development grants from the UGA Research Foundation. These grants will allow Glenn to construct a cDNA library for the American alligator; Neal will study magnesium incorporation in biogenic siderites.

Heather Brant won "Best Student Poster Presentation, First Place," at the annual Carolinas Chapter of the Society of Environmental Toxicology and Chemistry meeting in Charleston in April 2003.

Dr. Thomas Hinton received a certificate from the Acting Director of the Centers for Disease Control and Prevention in recognition of and appreciation for six years of service on the Citizen's Advisory Committee on Public Health Effects Subcommittee.

Susan Dietz, a student of **Dr. Barbara Taylor**, received the Outstanding Student Award from the Entomological Society of Pennsylvania in October 2002 for her M.S. thesis research.

Charles Davis was elected Second Vice-President of the South Carolina Wildlife Federation Board of Directors.

Several SREL research scientists were invited participants in the NSF-funded Tisza River Workshop in Budapest, Hungary. Funded by NSF, this collaborative effort was organized by **Dr. Domy Adriano** and researchers in Hungary. Other SREL participants included **Drs. William Hopkins**, **Brian Jackson**, **Charles Jagoe**, and **Lee Newman**.

Two SREL faculty members were featured on National Geographic television specials during the past year. **Dr. J. Whitfield Gibbons** and members of his research group were featured on the show "The Snake Wranglers," and **Dr. I. Lehr Brisbin** was featured in a special titled "The First Dog."

Externally Funded Grants

| | |
|-----------------------|--|
| PI | Paul M. Bertsch |
| Project Title | Effects of natural and anthropogenic compounds and suspended colloids on partition coefficients (K _d) for selected radionuclides and other inorganic contaminants |
| Funding Agency | US Environmental Protection Agency |
| Budget | \$100,000 total |
| Period | July 1, 2002–June 30, 2003 |
| PI | Paul M. Bertsch |
| Project Title | Linking Chemical Speciation, Desorption Kinetics, and Bioavailability of U and Ni in Aged-Contaminated Sediments: A Scientific Basis for Natural Attenuation and Risk Assessment |
| Funding Agency | US Department of Energy/Office of Science EMSP |
| Budget | \$478,000 total (\$239,000 in FY2002) |
| Period | September 1, 2002–September 30, 2005 |
| PI | Paul M. Bertsch |
| Project Title | The Environmental Fate of Arsenic from Poultry Litter |
| Funding Agency | U.S. Department of Agriculture |
| Budget | \$164,500 |
| Period | December 1, 2000–November 30, 2003 |
| PI | Paul M. Bertsch and Delma Bratvold |
| Project Title | Tidal Creek Materials Loading for the SC-GA LU-CES Program |
| Funding Agency | South Carolina Sea Grant Consortium |
| Budget | \$15,335 |
| Period | April 1, 2003–June 30, 2003 |
| PI | I. Lehr Brisbin, Jr. |
| Project Title | Wood Stork Foraging Behavior in the Coastal Environment |
| Funding Agency | USDI–U.S. Fish and Wildlife Service |
| Budget | \$28,280 |
| Period | September 1, 2000–December 31, 2003 |
| PI | I. Lehr Brisbin, Jr. |
| Project Title | Ecological Studies of Birds in the Vicinity of the Augusta Regional Airport at Bush Field and the Messerly Wastewater Treatment Plant |
| Funding Agency | The Augusta-Richmond County Consolidated Government |
| Budget | \$68,246 |
| Period | August 1, 2001–September 30, 2003 |
| PI | I. Lehr Brisbin, Jr. |
| Project Title | Ossabaw Research on Raccoons and Feral Hogs |
| Funding Agency | The Ecology Committee of Savannah Presbytery |
| Budget | \$9,100 |
| Period | July 1, 2002–November 15, 2003 |

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|-----------------------|--|
| PI | I. Lehr Brisbin, Jr. |
| Project Title | CLEARMADD |
| Funding Agency | Centers for Disease Control and Prevention |
| Budget | \$12,500 |
| Period | August 1, 2002–July 31, 2003 |
| | |
| PI | Beverly Collins |
| Project Title | Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics |
| Funding Agency | Strategic Environmental Research and Development Program (SERDP) |
| Budget | \$1,331,765 total |
| Period | January 1, 2000–December 30, 2004 |
| | |
| PI | J. Whitfield Gibbons |
| Project Title | Effects of Forestry Practices on the Gopher Tortoise |
| Funding Agency | Strategic Environmental Research and Development Program (SERDP) |
| Budget | \$50,000 |
| Period | FY2003 |
| | |
| PI | J. Whitfield Gibbons |
| Project Title | Development of Habitat Guidelines for Herpetofauna |
| Funding Agency | USDA Forest Service |
| Budget | \$112,000 in FY2003 |
| Period | corresponds to Cooperative Agreement (expires June 30, 2006) |
| | |
| PI | J. Whitfield Gibbons |
| Project Title | Development, Production, and Distribution of Environmental Education Materials for Indigo Snake Protection |
| Funding Agency | USDI Fish and Wildlife Service |
| Budget | \$7,416 (for a total award of \$93,316) |
| Period | May 1, 2001–September 30, 2005 |
| | |
| PI | J. Whitfield Gibbons |
| Project Title | Cooperative Agreement: The Inventory Report for the Southeast Coastal Network |
| Funding Agency | USDI National Park Service |
| Budget | \$20,741 (for a total award of \$250,032) |
| Period | April 1, 2001–April 24, 2006 |
| | |
| PI | J. Whitfield Gibbons |
| Project Title | Sublethal Effects of Pesticide Exposure |
| Funding Agency | U.S. Golf Association |
| Budget | \$29,200 |
| Period | February 1, 2001–January 31, 2004 |
| | |
| PI | J. Whitfield Gibbons |
| Project Title | PARC Web Site Development II |
| Funding Agency | National Fish and Wildlife Foundation |
| Budget | \$23,700 |
| Period | January 1, 2002–March 31, 2003 |

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| PI | J. Whitfield Gibbons |
| Project Title | A Primary Understanding of Our Environment: Teaching Kids the Science of Ecology |
| Funding Agency | The Christensen Fund |
| Budget | \$80,000 |
| Period | August 1, 2002–August 1, 2003 |
| PI | J. Whitfield Gibbons |
| Project Title | PARC-ARMI Database: Inventory, Monitoring, and Research Database for Amphibians and Reptiles on Federal Land |
| Funding Agency | U.S. Geological Survey |
| Budget | \$20,000 |
| Period | April 5, 2002–August 31, 2003 |
| PI | J. Whitfield Gibbons |
| Project Title | Inventory of Herpetofauna for the Appalachian Highlands and Cumberland Piedmont Networks of the National Park Service |
| Funding Agency | USDI National Park Service |
| Budget | \$37,226 |
| Period | September 9, 2002–December 31, 2004 |
| PI | J. Whitfield Gibbons |
| Project Title | Amphibian and Reptile Inventory of Sumter National Forest |
| Funding Agency | USDA Forest Service |
| Budget | \$20,000 |
| Period | September 18, 2001–September 30, 2004 |
| PI | J. Whitfield Gibbons |
| Project Title | To Inventory and Monitor Webster's Salamander (<i>Plethodon websteri</i>) on the Long Cane Ranger District of the Sumter National Forest |
| Funding Agency | USDA Forest Service |
| Budget | \$8,000 |
| Period | June 6, 2001–April 30, 2003 |
| PI | J. Whitfield Gibbons |
| Project Title | Development of Habitat Guidelines for Herpetofauna |
| Funding Agency | USDA Forest Service |
| Budget | \$60,000 |
| Period | August 28, 2000–September 30, 2002 |
| PI | William Hopkins |
| Project Title | Modeling the Individual and Interactive Risks to an Amphibian Population Resulting from Breeding Site Contamination and Terrestrial Habitat Loss |
| Funding Agency | US Environmental Protection Agency/University of Maryland |
| Budget | \$68,730 |
| Period | December 19, 2001–December 18, 2003 |
| PI | Charles H. Jagoe and J Vaun McArthur |
| Project Title | REU The Impact of Energy Technologies on Natural Environmental Systems |
| Funding Agency | National Science Foundation |
| Budget | \$64,600 |
| Period | May 1, 2001–April 30, 2003 |

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|-----------------------|---|
| PI | Charles H. Jagoe |
| Project Title | Environment Cooperative Science Center: Regional Studies in Sustainable Management of Coastal and Marine Habitats for Decision Making |
| Funding Agency | South Carolina State University/NOAA |
| Budget | \$52,148 |
| Period | October 1, 2001–September 30, 2002 |
| PI | Kenneth W. McLeod |
| Project Title | Assessment of Harvesting Bottomland Hardwood Sites on Plant Composition and Ecosystem Processes |
| Funding Agency | USDA Forest Service |
| Budget | \$114,930 |
| Period | February 1, 2002–January 31, 2004 |
| PI | Christopher S. Romanek |
| Project Title | Controlled Growth of Biologic and Abiotic Carbonates and Fe-oxides |
| Funding Agency | National Aeronautics and Space Administration |
| Budget | \$20,000 |
| Period | May 14, 1999–April 1, 2003 |
| PI | John C. Seaman |
| Project Title | Tritium Distribution, Mixing, and Transport at the Tritiated Water Management Facility Southwest Plume Interim Measures |
| Funding Agency | USDA Forest Service |
| Budget | \$33,170 (for a total award of \$93,301) |
| Period | October 1, 2001–September 30, 2003 |
| PI | John C. Seaman |
| Project Title | Colloid Stability and Size Analysis |
| Funding Agency | Education, Research & Development Association of Georgia Universities |
| Budget | \$7,740 |
| Period | August 15, 2002–November 14, 2002 |
| PI | Rebecca Sharitz |
| Project Title | Impacts of Military Training and Land Management in Threatened and Endangered Species in the Southeastern Fall Line/Sandhills Community |
| Funding Agency | Strategic Environmental Research and Development Program (SERDP) |
| Budget | \$939,523 total |
| Period | 2002–2005 |
| PI | Rebecca R. Sharitz |
| Project Title | Vegetation Establishment Success in Restored Carolina Bay Depressions on the Savannah River Site, South Carolina |
| Funding Agency | USDA Forest Service |
| Budget | \$43,750 |
| Period | August 6, 2001–March 31, 2004 |
| PI | Rebecca R. Sharitz and Virginia Jin |
| Project Title | Dissertation Research: Plant Organic Nitrogen Uptake in Temperate Terrestrial Ecosystems |
| Funding Agency | National Science Foundation |
| Budget | \$7,231 |
| Period | July 1, 2002–June 30, 2003 |

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|-----------------------|---|
| PI | Barbara E. Taylor |
| Project Title | Characterization of Invertebrate Assemblages in Carolina bays and other Wetland Ponds Before and After Restoration |
| Funding Agency | USDA Forest Service |
| Budget | \$5,000 |
| Period | August 29, 2002–September 30, 2003 |
| PI | Chuanlun Zhang |
| Project Title | Anaerobic Methane Oxidation in the Gulf of Mexico Gas Hydrate System: Implications for Biogenic Carbonate Formation |
| Funding Agency | University of North Carolina at Wilmington (subaward from NOAA grant) |
| Budget | \$49,634 |
| Period | January 1, 2002–June 30, 2003 |
| PI | Chuanlun Zhang |
| Project Title | Carbon Isotope Fractionations Associated with Bacterial Methane Oxidation: Implications for Carbonate Buildups at Hydrocarbon Seeps |
| Funding Agency | American Chemical Society |
| Budget | \$54,358 |
| Period | August 1, 2002–August 31, 2004 |
| PI | Chuanlun Zhang |
| Project Title | Using Carbon Isotopes to Evaluate the Effectiveness of Carbon Sequestration in Coal Fly Ash |
| Funding Agency | UT-Battelle, LLC |
| Budget | \$14,240 |
| Period | April 1, 2003–March 31, 2004 |
| PI | Chuanlun Zhang |
| Project Title | Biogeochemical Processes and Community Dynamics in Gas Hydrate Systems in the Gulf of Mexico |
| Funding Agency | National Science Foundation |
| Budget | \$250,680 (total award \$358,341) |
| Period | September 1, 2002–August 31, 2003 |
| PI | Christopher Romanek |
| Project Title | Fulbright Alumni Initiative Award |
| Funding Agency | Council for International Exchange of Scholars |
| Budget | \$11,720 |
| Period | June 1, 2003–May 30, 2005 |
| PI | J. Whitfield Gibbons |
| Project Title | Collaborative Research: Land-Use Practices and Persistence of Amphibian Populations |
| Funding Agency | National Science Foundation |
| Budget | \$59,513 |
| Period | May 15, 2003–April 30, 2004 |
| PI | Paul M. Bertsch and Heather Dion |
| Project Title | Women's International Science Collaboration Program |
| Funding Agency | American Association for the Advancement of Science |
| Budget | \$4,000 |
| Period | May 7, 2003–September 30, 2003 |

PUBLICATIONS

Journal Articles and Book Chapters Published

- 2608 Harper, S. J., J. D. Westervelt and A. Shapiro. 2002. Modeling the movements of cowbirds: application towards management at the landscape scale. *Natural Resource Modeling* 15:111-131.
- 2609 Perry, J. N. and P. M. Dixon. 2002. A new method to measure spatial association for ecological count data. *Ecoscience* 9:133-141.
- 2610 Adriano, D. C., J. Weber, N. S. Bolan, S. Paramasivam, B. Koo and K. S. Sajwan. 2002. Effects of high rates of coal fly ash on soil, turfgrass, and groundwater quality. *Water, Air, and Soil Pollution* 139:365-385.
- 2611 Boone, M. D., D. E. Scott and P. H. Niewiarowski. 2002. Effects of hatching time for larval ambystomatid salamanders. *Copeia* 2:511-517.
- 2612 Prince, K. L., T. C. Glenn and M. J. Dewey. 2002. Cross-species amplification among peromyscines of new microsatellite DNA loci from the oldfield mouse (*Peromyscus polionotus subgriseus*). *Molecular Ecology Notes* 2:133-136.
- 2613 Dion, H. M., L. K. Ackerman and H. H. Hill, Jr. 2002. Detection of inorganic ions from water by electrospray ionization-ion mobility spectrometry. *Talanta* 57:1161-1171.
- 2614 Chang, A. C., A. L. Page and Bon-Jun Koo. 2002. Biogeochemistry of phosphorus, iron, and trace elements in soils as influenced by soil-plant-microbial interactions. p. 43-57. In *Soil Mineral-Organic Matter-Microorganism Interactions and Ecosystem Health*, edited by A. Violante, P. M. Huang, J. M. Bollag, and L. Gianfreda. *Developments in Soil Science*, Vol. 28B, Elsevier, New York, NY.
- 2615 Ryan, T. J., T. Philippi, Y. A. Leiden, M. E. Dorcas, T. B. Wigley and J. W. Gibbons. 2002. Monitoring herpetofauna in a managed forest landscape: Effects of habitat types and census techniques. *Forest Ecology and Management* 167:83-90.
- 2616 Gaines, K. E., C. S. Romanek, C. S. Boring, C. G. Lord, M. Gochfeld and J. Burger. 2002. Using raccoons as an indicator species for metal accumulation across trophic levels: A stable isotope approach. *Journal of Wildlife Management* 66:811-821.
- 2617 DeVault, T. L. and O. E. Rhodes, Jr. 2002. Identification of vertebrate scavengers of small mammal carcasses in a forested landscape. *Acta Theriologica* 47:185-192.
- 2618 Adriano, D. C., N. S. Bolan, Bon-Jun Koo, R. Naidu, D. van der Lelie, J. Vangronsveld, and W. W. Wenzel. 2002. Natural remediation processes—bioavailability interactions in contaminated soils. p. 501-1-501-12. Symposium No. 42 of The 17th World Congress of Soil Science. Bangkok, Thailand. 14-21 Aug. 2002.
- 2619 Plague, G. R. and J. H. Larson. 2002. Analysis of an apparent genetic cline in the stonefly *Pteronarcys scotti* (Plecoptera: Pteronarcyidae). *Journal of Entomological Science* 37:278-280.
- 2620 Lord, C. G., K. F. Gaines, C. S. Boring, I. L. Brisbin, Jr., M. Gochfeld and J. Burger. 2002. Raccoon (*Procyon lotor*) as a bioindicator of mercury contamination at the U.S. Department of Energy's Savannah River Site. *Archives of Environmental Contamination and Toxicology* 43:356-363.
- 2621 Tatara, C. P., M. Mulvey and M. C. Newman. 2002. Genetic and demographic responses of mercury-exposed mosquitofish (*Gambusia Holbrooki*) populations: Temporal stability and reproductive components of fitness. *Environmental Toxicology and Chemistry* 21:2191-2197.
- 2622 Geebelen, W., J. Vangronsveld, D. C. Adriano, R. Carleer and H. Clijsters. 2002. Amendment-induced immobilization of lead in a lead-spiked soil: evidence from phytotoxicity studies. *Water, Air, and Soil Pollution* 140:261-277.
- 2623 Brant, H. A., C. H. Jagoe, J. W. Snodgrass, A. L. Bryan, Jr. and J. C. Gariboldi. 2002. Potential risk to wood storks (*Mycteria americana*) from mercury in Carolina Bay fish. *Environmental Pollution* 120:405-413.
- 2624 Punshon, T., D. C. Adriano and J. T. Weber. 2002. Restoration of drastically eroded land using coal fly ash and poultry biosolid. *The Science of the Total Environment* 296:209-225.

- 2625 DeVault, T. L. and A. R. Krochmal. 2002. Scavenging by snakes: An examination of the literature. *Herpetologica* 58:429-436.
- 2626 Duff, M. C., J. U. Coughlin and D. B. Hunter. 2002. Uranium co-precipitation with iron oxide minerals. *Geochimica et Cosmochimica Acta* 66:3533-3547.
- 2627 Brisbin, I. L., Jr., M. H. Smith and J. D. Peles. 2002. Contributions of radioecology to the development of some modern concepts of ecotoxicology: from ecological half-life to monitored natural attenuation. *Radioprotection-Colloques* 37:C1-179-C1-183.
- 2628 Geebelen, W., J. Vangronsveld, D. C. Adriano, L. C. Van Poucke and H. Clijsters. 2002. Effects of Pb-EDTA and EDTA on oxidative stress reactions and mineral uptake in *Phaseolus vulgaris*. *Physiologia Plantarum* 115:377-384.
- 2629 Dilustro, J. J., F. P. Day, B. G. Drake and C. R. Hinkle. 2002. Abundance, production and mortality of fine roots under elevated atmospheric CO₂ in an oak-scrub ecosystem. *Environmental and Experimental Botany* 48:149-159.
- 2630 Rodriguez-Navarro, A. B. and C. S. Romanek. 2002. Mineral fabrics analysis using a low-cost universal stage for X-ray diffractometry. *Eur. J. Mineral* 14:987-992.
- 2631 Brisbin, I. L., Jr., A. T. Peterson, R. Okimoto and G. Amato. 2002. Characterization of the genetic status of populations of red junglefowl. *Journal Bombay Natural History Society* 99:217-223.
- 2632 Dessauer, H. C., T. C. Glenn and L. D. Densmore. 2002. Studies on the molecular evolution of the crocodylia: footprints in the sands of time. *Journal of Experimental Zoology/Molecular Development & Evolution* 294:302-311.
- 2633 Glenn, T. C., J. L. Staton, A. T. Vu, L. M. Davis, J. R. A. Bremer, W. E. Rhodes, I. L. Brisbin, Jr. and R. H. Sawyer. 2002. Low mitochondrial DNA variation among American alligators and a novel non-coding region in crocodylians. *Journal of Experimental Zoology/Molecular Development & Evolution* 294:312-324.
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- 2635 Rodriguez-Navarro, A. B., K. F. Gaines, C. S. Romanek and G. R. Masson. 2002. Mineralization of clapper rail eggshell from a contaminated salt marsh system. *Archives of Environmental Contamination and Toxicology* 43:449-460.
- 2636 Rowe, C. L., W. A. Hopkins and J. D. Congdon. 2002. Ecotoxicological implications of aquatic disposal of coal combustion residues in the United States: A review. *Environmental Monitoring and Assessment* 80:207-276.
- 2637 White, D. L. and K. F. Gaines. 2002. The Savannah River Site: Site description, land use and management history. *Studies in Avian Biology* 21:8-17.
- 2638 Bryan, A. L., Jr., K. F. Gaines and C. S. Eldridge. 2002. Coastal habitat use by wood storks during the non-breeding season. *Waterbirds* 25:429-435.
- 2639 Krizek, B. A., V. Prost, R. M. Joshi, T. Stoming and T. C. Glenn. 2003. Developing transgenic Arabidopsis plants to be metal-specific bioindicators. *Environmental Toxicology and Chemistry* 22:175-181.
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- 2641 Congdon, J. D., R. D. Nagle, M. F. Osentoski, O. M. Kinney and R. C. van Lobel Sels. 2003. Life history and demographic aspects of aging in the long-lived turtle (*Emydoidea blandingi*). p. 15-31. In *Brain and Longevity*, edited by Finch, et al. Springer-Verlag Berlin Heidelberg.
- 2642 Reed, R. N., R. Shine and S. Shetty. 2002. Sea kraits (Squamata: *Laticauda* spp.) as a useful bioassay for assessing local diversity of eels (Muraenidae, Congridae) in the western Pacific Ocean. *Copeia* 4:1098-1101.
- 2643 Dietz-Brantley, S. E., B. E. Taylor, D. P. Batzer and A. E. DeBiase. 2002. Invertebrates that aestivate in dry basins of Carolina Bay Wetlands. *Wetlands* 22:767-775.
- 2644 Reed, R. N. 2003. Interspecific patterns of species richness, geographic range size, and body size among New World venomous snakes. *Ecography* 26:107-117.

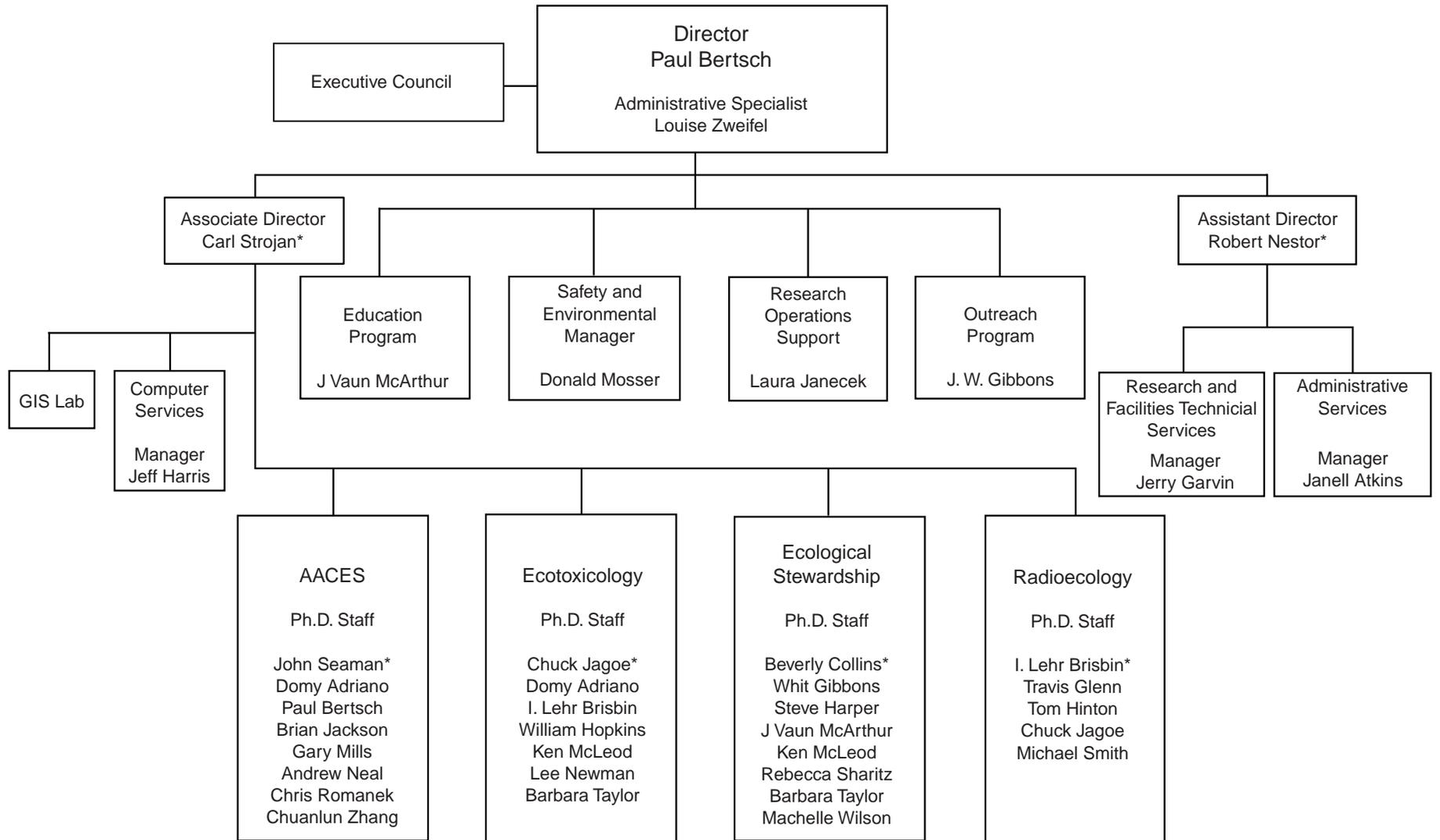
- 2645 Bolan, N. S., D. C. Adriano, S. Mani and A. Khan. 2003. Adsorption, complexation, and phytoavailability of copper as influenced by organic manure. *Environmental Toxicology and Chemistry* 22:450-456.
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FIGURE 1. Organizational Chart for the Savannah River Ecology Laboratory



* Denotes Group Representative to Executive Council



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