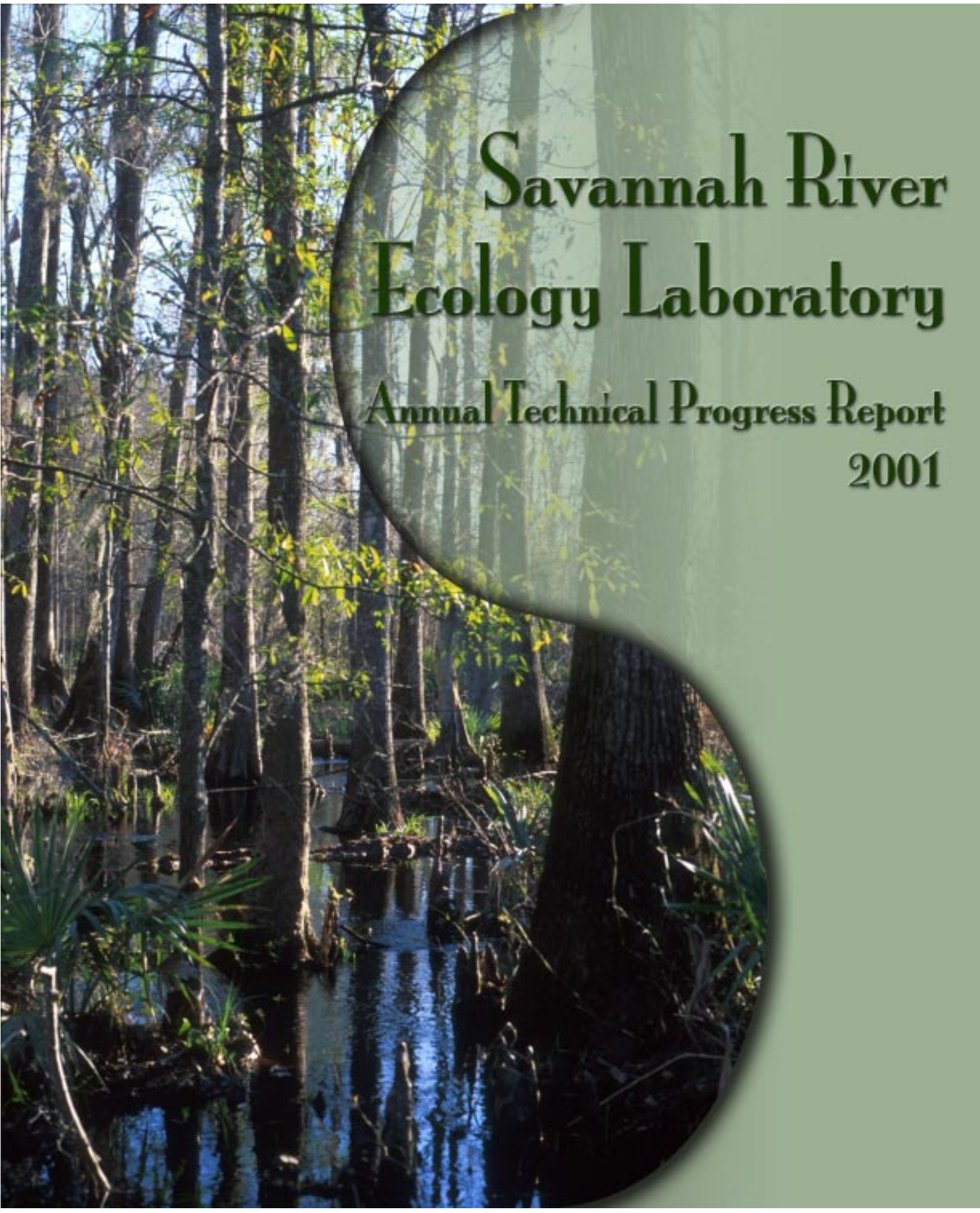

Savannah River Ecology Laboratory

Annual Technical Progress Report 2001

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 basic and applied environmental research, with emphasis upon expanding the understanding of ecological processes and principles, and upon evaluating the impacts of industrial and land use activities on the environment.

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, 1996 through June 30, 2001. The estimated total cost of this agreement is almost $60 million, with DOE contributing about $57 million and the University of Georgia about $3 million. Additional funding, about $1.33 million in FY'01, comes from other contracts and grants involving a variety of other organizations. SREL's total operating budgets from DOE in FY'98, FY'99, FY'00, and FY'01 were $9.6, $9.1, $8.9, and $8.1 million, respectively; the FY'02 budget is projected to be $8.95 million. SREL also receives almost $700,000 per year from The University of Georgia. During FY'01 an additional $1.4 million was received from DOE and WSRC for SRS-related research and outreach.

Staffing

The Savannah River Ecology Laboratory currently has a staff of about 150 people, most of whom are employees of The University of Georgia. The staff includes 18 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 12 Ph.D.s in other technical positions or postdoctoral appointments. Research technicians (45), clerical and other support personnel (45), and graduate students (35) 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 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 outreach program, and support services.

Facilities

The Savannah River Ecology Laboratory's main facility consists of a 45,000 ft^2 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 building, and a maintenance shop. A 5,000-ft^2 laboratory and additional offices are located in B-Area, about 5 miles from the main lab; and a 3,500-ft^2 radioecology laboratory is located at Par Pond, about 15 miles from the main lab. A 5,000-ft^2conference 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

- Four research groups with more than 30 program elements:
  - Advanced Analytical Center for Environmental Sciences
  - Ecological Stewardship
  - Ecotoxicology, Remediation, and Risk Assessment
  - Radioecology
- A new dual view ICP-OES instrument was installed that provides unsurpassed detection limits for trace elements and a wide linear range of concentrations for major element determinations. This should allow for the rapid analysis of soil digests and extracts.
- Four consecutive years of field surveys (1997-2000) revealed that the frequency of spinal malformations in bullfrog larvae developing in the ash basins ranges from 27-38%, up to 30 times higher than what is found in reference sites.
- Studies modeling natural attenuation and contaminant bioavailability at Steed Pond indicate that uranium, the main contaminant of concern, is not accumulating within plant tissues and herbivores, but data strongly suggest that there is considerable migration of Ni.
- Over twelve taxa of bacteria were identified from Four Mile Creek that are known opportunistic pathogens of humans. All isolates were antibiotic resistant.
- Benthic invertebrates, which are an important prey source for benthic feeding fish, accumulate extremely high concentrations of at least 12 toxic trace elements.

- An irradiation facility now exists on the SRS where the effects of waste in combination with radioactive contamination can be tested on aquatic organisms. This unique facility is unlike any other within the United States.
- The monitoring of Rainbow Bay reptiles and amphibians continued for its 23rd year, as recommended by the SRS Citizens Advisory Board.
- Post-thermal Pen Branch has significantly less stored benthic organic matter and less particulate matter in transport during fall than does a reference stream. Organic matter inputs peaked earlier in Pen Branch, indicating differences both in riparian species and phrenology compared to a control stream.
- Concentrations of heavy metals other than mercury (Cd, Co, Cu, Mn, Ni, Pb, and Zn) in fish from SRS reservoirs do not appear high enough to cause concern to wildlife consumers.
- Isotope ratio mass spectrometry was used to characterize the origin of contaminants (i.e. Hg) found in the tissues of endangered species known to forage on or near the Savannah River Site.
- AACES researchers have demonstrated that hydroxylapatite, a typical phosphate-containing fertilizer amendment, will immobilize metals such as nickel, copper, chromium, aluminum, and lead in sediments with minimal ecological disturbance. Preliminary studies have also demonstrated that chemical immobilization of the metal contaminants is accompanied by reduced bioavailability to microorganisms and mitigation of Ni toxicity

- The Burma Road coneflower population fluctuates, but is declining over time. Management treatments such as cutting and burning have not altered the slow population decline.
- Only two of six fish species studied from the Savannah River showed differences in contamination levels between upstream vs. adjacent vs. downstream locations from the SRS, and one of them was actually more contaminated at the upstream location. No fish from either the river or Steel Creek exceeded the radiocesium limit for meat for human consumption as set by the European Economic Community (0.6 Bq/g fresh weight).
- A molecular marker has been successfully developed for assaying the frequency of chromosome damage in turtles.
- Publication of one book: *Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability, and Risks of Metals*
- Publication of 83 journal articles, with an additional 77 articles submitted or in press.
- Funding for 29 grants totaling $1.330M in FY'01.
- Faculty positions in 9 University of Georgia departments and adjunct faculty positions at 15 other universities.
- Service on over 65 editorial boards/committees.
- Presentation of more than 100 scientific presentations and lectures.
- Fifteen undergraduate and 35 graduate students conducting research.
- SREL students were awarded 2 masters and 3 doctorate degrees in FY'01.
- In the last year, SREL sponsored 2 co-op students from local universities in its Computer Services Department.
- SREL personnel include 30 Ph.D. level scientists with 45 supporting technicians.
- The Laboratory continues to maintain state-of-the-art analytical capabilities.

Community, State, And Regulator Relationships

- Provided technical support for site visits from South Carolina Department of Health and Environmental Control (SCDHEC), Georgia Department of Natural Resources, and Environmental Protection Agency (EPA) staff.
- The SREL Outreach Program reached the general public through more than 310 events in an attempt to improve scientific literacy. Topics for these presentations included biodiversity, animal adaptations, plants and wetlands, local ecosystems and conservation, classification, and careers in ecology and research.
- The third printing of a publication from the Savannah River Ecology Laboratory entitled *Snakes of Georgia and South Carolina* provides information on identifying and understanding the 40 species of snakes in Georgia and the 38 in South Carolina. The lab partnered with 19 organizations in the third printing of this publication.
- 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.
- SREL participated in the 50th Anniversary of the SRS by conducting a series of EcoTours that focused on the ecological health of the SRS. SREL's exhibits were extremely popular during the SRS Family Days weekend.

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 $700,000 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 700 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 of the Natural Resources Coordinating Committee 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) in South Carolina for 50 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) SRS near Aiken, South Carolina.

The Laboratory's research mission during the 2001 fiscal year was fulfilled with the publication of one book and 83 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 and graduate students received awards. These are described in the section Special Accomplishments of Faculty, Staff, Students, and Administration on page 54.

Notable scientific accomplishments include work conducted on contaminant transport, global reptile decline, phytoremediation, and radioecology.

- Dr. Domy Adriano authored the second edition of his book *Trace Elements in Terrestrial Environments: Biogeochemistry, Bioavailability, and Risks of Metals*, which was recently published by Springer-Verlag. The book provides a comprehensive treatment of many important aspects of trace elements in the environment. The first edition of the book, published in 1986, has become a widely acclaimed and cited reference.
- International attention was focused on the problem of reptile species decline with the publication of an article on this topic in the journal *BioScience* in August, 2000. The article's authors included Dr. Whit Gibbons and a number of other SREL herpetologists who researched the growing worldwide problem of decline of reptile species. Factors related to these declines include habitat loss and degradation, introduction of invasive species, environmental pollution, disease, global climate change, and unsustainable commercial use. The conclusion reached by the article is that the disappearance of reptiles from the natural world is genuine and should be a matter of concern; current evidence suggests that these declines constitute a worldwide crisis.
- SREL's research in the area of phytoremediation was enhanced with the addition of Dr. Lee Newman as a faculty member in January 2001. Dr. Newman, an internationally recognized authority in the field, holds a joint appointment with the University of South Carolina and SREL. She is developing a collaborative program in phytoremediation on the SRS and offsite.
- Work is nearing completion on SREL's outdoor mesocosm irradiation facility, which is designed for studying the effects of low-level radiation doses on organisms. The 1-acre facility at Par Pond consists of 48 fiberglass tanks that can maintain small organisms such as fish and amphibians. Thirty of the tanks have sealed ^{137}Cs sources suspended above them containing either 0.02, 0.2,

or 2.0 Ci. These sources can deliver average dose rates of 4, 40 and 400 mGy per day, respectively, to organisms under replicated conditions.

A major accomplishment during the past year was renewal of SREL's Cooperative Agreement with the Department of Energy. A new five-year cooperative agreement, signed by DOE during late FY'01, became effective 1 July 2001. The total DOE contribution toward this agreement is expected to be $53 million over five years; the UGA contribution is expected to equal at least $6 million. During FY'01 SREL also signed a Memorandum of Understanding with the University of South Carolina–Columbia, which pledges that both institutions will work together over the next five years to secure funding for several jointly funded faculty positions. Such positions would be modeled after the joint USC-SREL position for Dr. Lee Newman, who holds a tenure-track position through the USC School of Public Health.

Another major achievement for SREL during the past year was completion of a new Laboratory Strategic Plan. An *ad hoc* Strategic Planning Committee comprised of representatives from throughout the Laboratory drafted the plan, which was then made available to all Lab personnel for comment. The final plan was launched by Director Paul Bertsch in February 2001 at a lab-wide "State of the Lab" meeting. The mission of SREL, as articulated in this new plan, is "to better understand the environment by acquiring and communicating knowledge that contributes to sound environmental stewardship." The SREL vision is to "be recognized internationally for integrated multidisciplinary research in the ecological and environmental sciences."

Four high level strategic goals were identified for SREL, including:

- Achieve excellence in research in ecological and environmental sciences.
- Increase awareness of SREL research and the importance of environmental stewardship among SRS stakeholders and the general public.
- Strengthen communication and training within SREL.
- Provide a work environment that promotes achievement of the SREL mission.

Desired outcomes were articulated as objectives under each goal, and the strategies that will be used to track progress toward achievement of each objective were outlined. An effort was made to define strategic goals that are institution-wide so that every member of the research, outreach, or support staffs can contribute in some way toward achievement of the overall goals. Progress in achievement of the strategic plan objectives will be tracked regularly throughout the year and the *ad hoc* Strategic Planning Committee will meet every six months to review progress.

SREL's research in the area of phytoremediation was enhanced this year with the addition of Dr. Lee Newman to the research faculty in January 2001. Dr. Newman holds a joint appointment with the University of South Carolina and SREL. SREL also advertised for two additional research faculty positions during FY'01—a statistician and a GIS/remote sensing specialist. Interviews were conducted for both positions and a statistician was hired and will join the faculty on 1 October 2001. Negotiations are still ongoing with a candidate for the GIS/remote sensing position.

Researchers at SREL currently have funding totaling $1.33M from 29 grants in addition to funds provided by DOE-SR. Sources of grant awards range from private agencies such as U.S. Golf Association to federal agencies such as the U.S. Fish and Wildlife Service and the National Science Foundation. Important grants received this year included an award of $158,000 to Dr. Whit Gibbons to conduct herpetological surveys of 18 National Parks in the Southeast and an award of $164,000 to Drs. Paul Bertsch and Brian Jackson from the Department of Agriculture, to study the environmental fate of arsenic from poultry litter. An additional $1.4M was received from DOE and WSRC for SRS-related research and outreach.

During FY'01 SREL purchased nineteen major equipment items, keeping the Laboratory on the cutting edge of ecological and environmental science. These items cost a total of $773,515 and were supported by matching funds from both DOE ($423,515) and UGA ($350,000). Major equipment acquisitions included a laser ablation system, an optical emission ICP-MS, and a collision cell ICP-MS. Most of these instruments have all been received by SREL and are already being used to support Lab research and outreach programs.

Participants in the SREL Education Program during FY'01 came from schools located throughout the United States and included 15 undergraduate students and 35 graduate students. The graduate students came from nine different universities in the U.S. and abroad, emphasizing the national and international stature of the SREL program. In the past year two graduate students from SREL earned Masters Degrees and three 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 nine departments at the University of Georgia, various SREL faculty have adjunct status at 15 other colleges and universities. Faculty, staff, and students also are active in providing outreach and service to the scientific community. Representatives from the SREL hold more than 65 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 216 talks, 52 tours, 19 exhibits, and 30 workshops, for a total of 77,000 people reached. Topics of these presentations included biodiversity, animal adaptation, plants and wetlands, 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 it is in its third printing. Several other educational products produced during the past year included a flier on "An Amphibian's Eye View of Wetlands," produced in cooperation with the National Audubon Society; a children's comic book entitled "Stepping into Ecology: the Ecological Adventures of Mud E. Boot," produced in cooperation with the Medical University of South Carolina's Environmental Biosciences Program; a flier on "Is it a Water Moccasin?" produced in partnership with the Georgia Department of Natural Resources Nongame-Endangered Wildlife Program; 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 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 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. During the past year, three of the five initial students completed course work toward their degrees. Five additional students completed the first year's course work, and five new students are expected to enroll and begin classes in the fall of 2001. In an effort to expand their audience, the SREL Outreach Program presented 12 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. SREL has phased out two Master's degree programs in Computer Science and Technical Communications offered by Southern Polytechnic State University that were not related to current SREL core research programs.

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 69 scientific meetings and environmental education programs for students, teachers, and the general public this past year. 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, and hosting an annual auction benefiting the South Carolina Chapter of The Nature Conservancy.

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. Multi-disciplinary 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 (ETRRA)*
- *Radioecology*

ADVANCED ANALYTICAL CENTER FOR ENVIRONMENTAL SCIENCES (AACES)

Advanced analytical and spectroscopic techniques provide an opportunity to generate new scientific knowledge needed for developing novel waste isolation and stabilization technologies, as well as 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 no remedial action, 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: nuclear magnetic resonance spectroscopy, synchrotron X-ray absorption spectroscopy, accelerator mass spectrometry, ion cyclotron resonance mass spectrometry, atomic force microscopy, and solid-state tunable laser spectroscopy.

AACES is organized around three interactive research programs in:

- *Environmental chemistry/hydrogeochemistry;*
- *Analytical applications and technology development; and*
- *Environmental computational chemistry.*

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 ecosystem level;*
- *Establish the infrastructure to provide 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, 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, 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.

- Time resolved luminescence at liquid nitrogen temperatures using the OPO tunable laser and the newly installed fast electronics was successfully deployed for uranium speciation in Steed Pond sediment samples.
- Micro-EXAFS and micro-diffraction techniques have been successfully deployed at the hard X-ray micro-probe, X26A, at the National Synchrotron Light Source at Brookhaven National Laboratory. 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.
- Methodology was developed to interface size exclusion chromatography with ICP-MS. Interfacing these two technologies will allow for the study of trace metal interactions with macromolecules such as fulvic acids, proteins, and peptides and will provide further information on contaminant cycling in contaminated systems.
- A new dual view ICP-OES instrument was installed that provides unsurpassed detection limits for trace elements and a wide linear range of concentrations for major element determinations. This should allow for the rapid analysis of soil digests and extracts.
- A new dynamic reaction cell (DRC) ICP-MS was installed to replace the older quadrupole ICP-MS. The DRC option will provide a much lower detection limit for V, Cr, Fe, As, and Se compared to the previous instrument.
- Field flow fractionation capabilities were developed for characterizing environmental particulates and high molecular weight

organics. The technique was compared with recently developed automated scanning electron microscopy (SEM) techniques that reduce instrument and operator bias.

- Changes in the zeta potential of microbial suspensions grown in the presence of organic contaminants were determined by laser doppler velocimetry as part of a collaboration with Dr. P. Morris from the Medical University of South Carolina.
- A dual inlet peripheral device was acquired for the isotope ratio mass spectrometer. The device expands the capabilities of the instrument to include chlorine and bromine stable isotope analysis. The inlet also provides an independent method for the characterization of international standards that must be analyzed to make accurate isotope measurements.
- Researchers from over ten universities and four governmental agencies, from the U.S. and abroad, either visited SREL to use the isotope ratio mass spectrometer or collaborated with researchers from SREL on environmental and ecological projects using data generated by the instrument.
- The capability of the Atomic Force Microscope was enhanced to include magnetic force microscopy (MFM). MFM permits the characterization of magnetic domains in material at a resolution of approximately 50 nanometers.
- Fourier transform mass spectrometry was employed to identify a mixture of alkylphenol polyethoxalates in TNX wastewater. This study was a collaborative effort with SRTC to identify the source of toxicity in effluents discharged into an SRS stream.
- Off-axis electrospray ionization was used in conjuction with Fourier transform mass spectrometry to identify and quantify acyl homoserine lactones derived from hydrocarbon-degrading bacteria. This work was part of ongoing bioremediation studies with the environmental microbiology group at the Medical University of South Carolina.
- High-resolution gas chromatography and gas chromatography-mass spectrometry was used to perform congener specific analysis of polychlorinated biphenyls (PCBs) in bird tissues. This work was performed in collaboration with the U.S. Fish and Wildlife Service.

Environmental Remediation and Waste Minimization

Principal Investigators: Domy C. Adriano, Paul M. Bertsch, Gary L. Mills, Christopher S. Romanek, John C. Seaman, and Brian 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., Hg- and Se-bearing components), 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 state, fate, and source 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.

- A treatability study, in cooperation with the USFS-SR (Forest Service) and ER (Environmental Restoration) was re-established in February 2001 in the 488D-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 structure that roots cannot easily penetrate. Seedlings are growing much better on plots amended with either the topsoil, fly ash, or biosolid.
- Surface water samples were collected from the D-Area Coal Pile Runoff Basin (DCPRB), the 488-D Ash Basin (DAB), and two seeps emanating from DAB for the phsicochemical characterization of surface and subsurface water associated with these waste units. These data were used to evaluate potential remedial efforts at DAB that were initiated in cooperation with the USFS-SR (Forest Service) and ER (Environmental Restoration).
- Laboratory experiments were conducted to characterize the chemistry and kinetics of Fe-carbonate and -oxide minerals that form when acid-sulfate waste waters are remediated using Constructed Treatment Wetland technologies. These minerals have been shown to sequester metals commonly found as contaminants in acid-sulfate waters.
- The Tims Branch/Steed Pond system received more than 45 MT of uranium and large quantities of other metals, such as nickel, copper, chromium, aluminum, and lead as a result of SRS operations. We have demonstrated that hydroxylapatite, a typical phosphate-containing fertilizer amendment, will immobilize these metals in sediments with minimal ecological disturbance. Preliminary studies have also demonstrated that chemical immobilization of the metal contaminants is accompanied by reduced bioavailability to microorganisms and mitigation of Ni toxicity.
- Sequential chemical extraction of metal-contaminated soils can be used to evaluate the potential efficacy of soil remediation techniques. It can also serve as an indicator of natural attenuation. In addition to modifyinpartition coefficient that includes 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.
- Triethylphosphate (TEP), injected as a gas into the subsurface, can stimulate the biodegradation of petroleum hydrocarbons and chlorinated solvents. The use of this clean-up technology has been developed and patented (tradename PHOSter) by WSRC-SRTC for remediation of waste sites. We have conducted studies to evaluate the behavior of TEP in subsurface environments on the SRS. The results indicate that sorption of TEP to clay mineral, oxides and organic matter is negligible and that TEP is readily bioavailable for uptake by microorganisms. The rate of abiotic hydrolysis of TEP is very slow and in not enhanced by surface catalyzed reactions.

However, hydrocarbon degrading microorganism mediate hydrolysis to initially diethylphoshate and subsequently, orthophosphate.

- The use of passive diffusion membrane samplers (PDMS) has been suggested as an alternative to well sampling for the collection of groundwater samples contaminated with volatile organic compounds. In collaboration with scientists from Bechtel Savannah River, Inc, we have evaluated the use of both gas and water PDMS for monitoring PCE and TCE in a contaminated groundwater plume derived from the CBRP at the SRS. Results indicate that air samplers correlate only weakly with water sample concentrations. However, water-filled PDMS yield good agreement with pumped well samples are a acceptable alternative approach to sample collection.

Environmental Chemistry and Transport of Contaminants

Principal Investigators: Paul M. Bertsch, Gary L. Mills, 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., ^{90}Sr and ^{137}Cs) 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 spectroscopic 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.

- Studies of radionuclides (U) and metals (Ni, Cr, Cu, and Pb) in aged contaminated soil and sediments revealed that the propensity and rates of incorporation into Fe-oxide mineral phases are critical mechanisms controlling natural attenuation processes of these contaminants.

- Collaborative studies with researchers at the Medical University of South Carolina have demonstrated that Ni in the Steed Pond system is toxic to a variety of microorganisms, including those responsible for degrading TCE. The studies have also revealed that the toxicity of Ni to a number of microorganisms is greatest at pH 5 rather than pH 6 or 7.
- Preliminary studies have demonstrated the importance of hydroxy interlayered vermiculites, the last remaining relics of weathered micaceous minerals, at controlling Cs sorption dynamics in upper Coastal Plain soils typical of the SRS.
- Synchrotron X-ray microprobe analyses of sediments from Steed Pond suggest that U and Ni are partitioning to distinct Fe-bearing mineral phases that are intimately associated.
- Initial toxicity studies with nematodes and earthworms exposed to Steed Pond and Tim's Branch sediments indicate evidence for significant mortality relative to control sediments.
- Using the Unsaturated Flow Apparatus (UFA), a series of experiments were initiated to evaluate the impact of land disposal of coal combustion fly ash on soil hydraulic conductivity and the migration of ash-derived contaminants as a function of degree of saturation.
- Ongoing field studies in collaboration with Drs. Sunnie Aburime, Clark Atlanta University (CAU), and John Blake, SRS-Forest Service, continue to evaluate solute migration within an irrigated watershed. Tritium containing irrigation water will be used as a tracer to evaluate water movement in the soil profile and evapotranspiration processes within the forest canopy.
- Isotope ratio mass spectrometry was used to characterize the origin of contaminants (i.e. Hg) found in the tissues of endangered species know to forage on or near the Savannah River Site.
- At the D-Area complex, a TCE-contaminant plume has intersected a portion of a fly ash/reject coal disposal basin. Sorption studies examining the interaction of TCE with the coal residue materials showed complete sorption/sequestration of the TCE into basin matrix. Ongoing studies are evaluating the relative contributions of sorption and abiotic degradation on this process.

ECOLOGICAL STEWARDSHIP

Most (90%) of the Savannah River Site (SRS) is not industrialized. These lands nevertheless are susceptible 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 into these lands. Management of the SRS requires data-intensive research and monitoring that provides meaningful land stewardship recommendations to minimize ecological risk and promote ecosystem health. This program includes research relevant to ecological land management, ecosystem health, 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 will:

- *Assess the current status of 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.*

The Ecological Stewardship Program will interface 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 develop workshops that explore and establish new approaches to land use and ecological risk assessment.*

Research on SRS Herpetofauna in Monitored Natural Attenuation Studies and to Assess the Distribution of Sensitive Species and Examine Biodiversity Patterns on a Protected Site

Principal Investigator: J. Whitfield Gibbons

The southeastern United States has the highest biodiversity and abundance of reptile and amphibian species in North America. Because of the rich herpetofaunal biodiversity on the U.S. Department of Energy's (DOE) Savannah River Site (SRS), this public land area has been the focus of extensive inventory and research since 1951 and has become the most prolific single site for herpetological research in the world. 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, resulting in the documentation of more species of herpetofauna (1,000,000+ individuals of 100+ species) than have been reported from any other public land area in the United States.

The goal of current studies is to capitalize on this enormous database and herpetological experience by supplementing previously collected information with studies designed to enhance DOE's environmental commitment, involving issues as diverse as documenting potential responses (e.g., mutations) of organisms to local contamination, determining distribution and abundance of sensitive species that have potential for regulations that could restrict site activities, conducting monitored natural attenuation programs, and establishing the extent of dispersal of organisms from radioactively or chemically contaminated sites. All of these projects have been natural extensions of an original goal of documenting the SRS as one of the most highly diverse tracts of land in the Upper Coastal Plain as a consequence of long-term environmental protection of native habitats. These studies serve to confirm the assumption that environmental health of the SRS is high in comparison to surrounding regions as well as having direct applicability to the Endangered Species Act, the site initiative of environmental cleanup, and to DOE Land Use and Facilities Management policies and environmental stewardship. It is our recommendation, 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. These studies focus on herpetofauna, which include two major vertebrate groups, the amphibians and reptiles, found on the SRS.

- SREL continues to be recognized nationwide as a major site for herpetological research and education.
- SREL continues to operate the Partners in Amphibian and Reptile Conservation (PARC) national Web site (www.parcplace.org), to serve as the nexus for herpetofaunal databases throughout the country. More than 50,000 copies of the book “Snakes of Georgia and South Carolina” have been distributed, and most have been paid for by outside sponsors in the private sector as well as state and federal agencies.
- The herpetology website (http://www.uga.edu/srelherp/) continues to be developed and refined. This site has been visited by more than 47,000 viewers and has generated numerous queries from interested individuals.
- The monitoring of Rainbow Bay reptiles and amphibians continued for its 23rd year, as

recommended by the SRS Citizens Advisory Board.

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 clean up.

- Initial DGGE analyses of *mer* and antibiotic resistant bacteria were performed to assess differences among bacterial assemblages found along Four Mile Creek.
- We identified over twelve taxa of bacteria that are known opportunistic pathogens of humans from Four Mile Creek. All isolates were antibiotic resistant.
- Gene exchange experiments are under way with colleagues from MCG.
- We have completed an analysis of the *mer* gene complex in bacteria found in Four Mile Creek. *Mer* confers resistance to Hg. We found that bacterial DNA extracted from sediments collected above and below the confluence of Castor Creek with Four Mile Creek had similar *mer* genes but that DNA from the area near the confluence was very different. Antibiotic resistance at this same location was the highest recorded for Four Mile Creek.

Land Management Effects on Nitrogen Cycling and Contaminant Movement in SRS Watersheds

Principal Investigators: Beverly S. Collins, J Vaun McArthur, Rebecca R. Sharitz, Christopher S. Romanek, John C. Seaman, and Thomas G. Hinton

This program is a large-scale, multidisciplinary study of the potential effects of SRS land use on nitrogen transformations in the uplands and radiocesium (^{137}Cs) mobility in streams that drain SRS watersheds. Forest management such as clearcutting and burning can affect nitrogen cycling and movement from uplands to floodplains. It is known that ammonium (NH_4^+) can displace ^{137}Cs from clay minerals and organic colloids. Thus, activities that increase NH_4^+ levels in contaminated floodplain sediments have the potential for increasing the mobility of ^{137}Cs in these fluvial systems.

The initial focus of this program was on ^{137}Cs levels and mobility in the Lower Three Runs Creek (LTR) watershed. This research provided DOE with data that characterized ^{137}Cs distributions in the sediments of the Lower Three Runs Integrated Operable Unit. Sampling near Donora Station on LTR revealed a patchy radiocesium distribution within sediments. Most activity occurred in floodplain sediments. The sand size fraction constituted the greatest mass of sediment and highest total activity for each sample. However, the highest concentration of ^{137}Cs always resided in the clay-size fraction.

In the second phase of this program, we are monitoring effects of forest management on nitrogen cycling. This research has provided pilot data for, and extends, research on thresholds of disturbance: land management effects on vegetation and nitrogen dynamics at Fort Benning, Georgia. In 1999, lysimeters were installed along a topographic gradient from managed upland pine forest to bottomland hardwoods along Meyers Branch. Additional lysimeters were installed in summer, 2000 and spring, 2001, along hardwood slopes scheduled for thinning or harvest. Nitrate (NO_3) and ammonium (NH_4) are being measured over time in lysimeter samples and additional experiments on litter decomposition are being conducted, to elucidate forest management effects on nitrogen cycling. Disturbance due to forest management activities can result in nitrogen loss from uplands to bottomlands, and can potentially influence contaminant movement through watersheds.

- Drought prevented comprehensive lysimeter data during summer and fall, 2000.
- In all sites and before tree harvesting or burning, NH_4-N in lysimeter samples decreased from uplands to slopes and increased from slopes to bottomlands during late winter and early spring. Bottomland samples averaged 0.165 ppm NH_4-N, which could be available to plants and interacts with contaminants in floodplain sediments.
- NO_3+NO_2-N in lysimeter samples taken during late winter and spring decreased from uplands to bottomlands in two sites, but showed no trend along the topographic gradient at Meyers Branch. Nitrate+nitrite ranged from undetectable to 0.03 ppm in upland samples, and averaged 0.08 ppm in bottomland samples.

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, TN 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.

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. 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, but is declining over time. From 1997 through 2000, there were 137, 156, 130, and 95 plants, with an average 1.7 stems per plant. Management treatments (cutting, burning) in 1992 and 1993 did not alter the slow population decline.
- The Road B-9 coneflower population fluctuates. From 1999 to 2000, a drought

year, number of stems declined from 1,929 to 1,698. There were 518 plants in 2000, with an average 3.3 stems per plant.
- The Tennessee Road coneflower population, first censused in 2000, had 204 plants and 517 stems, for an average 2.5 stems per plant.
- The proportion of flowering stems in the three coneflower populations were 7.7% in the Tennessee Road population, 8.3% in the Burma Road population, and 13% in the most open, Road B-9 population.
- SREL and USFS-SR cosponsored a symposium titled "Issues in Ecology and Management of Rare Plants of the Southeastern Piedmont and Coastal Plain" on September 9, 1999 at the SREL Conference Center. Papers from the symposium were published as a special theme issue of Natural Areas Journal volume 21(1), 2001.

Phytoremediation of Contaminants in Constructed and Natural Wetlands

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

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.

In 1997, water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) seedlings were planted in the F-Area seepline. Through the summer of 2000, 20% of the water tupelo had died, but none of the baldcypress. Leaf samples taken each year indicate the manganese and cobalt concentrations continue to rise by about 10% per year. Presently, water tupelo leaf Mn and Co concentrations are 5260 and 389 ppm, respectively. These concentrations are 20 and 200 times higher in water tupelo than in bald cypress. 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.

- Two woody species from a weedy genus *Sesbania*, have had minimal biomass reduction while maintaining adequate contaminant uptake rates, although neither species is a hyperaccumulator species.
- Few water quality differences have been found between treatments with real and plastic plants. Amounts of nitrate and ammonia were reduced relative to the plastic mimics but all metals, and concentrations

were similar.

- Bacterial assemblages associated with real and plastic plants were different as determined by physiologic assays, i.e., Biolog3® plates. However, the overall functioning of the assemblages seem to be similar give the end-of-pipe water quality analysis.

Restoration Ecology of Highly Impacted Forested Floodplain Ecosystems

Principal Investigators: J Vaun McArthur, 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, 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.

- Although originally planted in 1993, survival of tree seedlings in the herbaceous competition control experiment continues to change. Between 1996 and 2000, survival of *Quercus phellos* and *Taxodium distichum* was unchanged, and declined only slightly for Q. lyrata, *Q. nuttallii*, and *Q. falcata var. pagodaefolia* (which had low survival from the first year). Survival of these species was not affected by the herbaceous control treatments. In contrast, survival of *Nyssa aquatica* continues to decline from 62% in 1996 to 34% in 2000 with significantly reduced survival in the herbaceous control treatments as opposed to the control, which still had 57% survival.
- In the willow removal experiment, planted in 1994, survival of *Quercus lyrata* and *Toxodium distichum* was unchanged, while survival of *Carya aquatica* declined from 83 to 69%. None of these species were affected by willow removal. Hence, the cost of willow removal does not need to be incurred to promote survival of these species in this habitat.
- From the results of both of these experiments, slight to significant declines in tree survival can be anticipated to occur over time, even where overall survival is high. The most important finding from these studies is that it is unnecessary to incur the resource and labor costs necessary to reduce herbaceous or willow competition in order to maximize tree survival.
- Seed banks of the planted sites in Pen Branch were more abundant than those of unplanted sites, but the composition of the seedbanks did not match the extant or present vegetation at any site.
- Seedbanks in the disturbed sites were dominated by herbs, sedges and rushes, while undisturbed sites had greater numbers of woody species.
- Post-thermal Pen Branch has significantly less stored benthic organic matter and less particulate matter in transport during fall. Organic matter inputs peaked earlier in Pen Branch indicating differences both in riparian species and phrenology. Since macroinvertebrates life cycles are keyed to both timing and source of organic matter input these data suggest that organic matter processing is still significantly different in Pen Branch than in reference streams.

- Pen Branch is wider and more entrenched with fewer debris dams and less interaction between the stream and floodplain. More organic matter is stored in the floodplain of the impacted stream than the reference stream indicating less interaction between the stream and the floodplain.

Restoration of Longleaf Pine/Sandhills Communities

Principal Investigators: Kenneth W. McLeod and Beverly S. Collins

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. Along the fall line sandhills which remain, fire suppression has allowed less fire-tolerant oak species (turkey oak, scrubby post oak, bluejack oak) to increase in importance while longleaf pine has declined. Natural stands of the various longleaf pine community types are uncommon. Reductions in the extent of these communities have limited several plant and animal species such 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.

This program is currently being leveraged by a grant from Strategic Environmental Research and Development Program (SERDP) Ecosystem Management Program (SEMP) to Beverly Collins, Tom, Hinton, J Vaun McArthur, Chris Romanek, John Seaman, Rebecca Sharitz, and two other non-SREL Principal Investigators. This grant supports research in another sandhills site at Ft. Benning near Columbus, GA.

- SREL hosted the Partners Along the Fall Line Sandhills Ecology and Ecosystem Management Workshop on March 6 and 7, 2001. This workshop met at SREL's Conference Center due its current SERDP SEMP grant conducting research at Ft. Benning and its 50-year legacy of ecological research on the management of federal lands in the sandhills region of the Southeast. The workshop was attended by over 70 researchers and land managers from universities, Department of Energy, Department of Defense, Environmental Protection Agency, Forest Service, Fish and Wildlife Service, and Nature Conservancy.

Wetland Restoration and Ecosystem Sustainability

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

Isolated wetland depressions such as Carolina bays are abundant throughout the southeastern Coastal Plain, but most of them have been ditched and many have been drained so that they no longer function as wetlands. The Savannah River Site (SRS) has approximately 400 of these depression wetlands, many of which were drained by previous landowners or have been disturbed by SRS land management activities. The U.S. Department of Energy (DOE) is committed to restoring disturbed wetlands to mitigate wetland losses and to demonstrate good land management practices. 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. 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.

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. We have selected 20 drained bays for study. Of these, 16 are being restored using techniques suggested from a pilot study and 4 will remain as controls. We have also identified an additional set of undrained bays that are functioning as wetlands to serve as reference sites.

The prescription for restoration is to close the drainage ditches, remove woody vegetation, and plant 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, we are testing two alternative strategies for managing the wetland margins. 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 focus on the vegetation and wetland invertebrate communities.

Pre-restoration characterization of the hydrology, soils and biota of the bays was completed in 2000. The bays have been mapped, and the potential mitigation credits for the DOE-SR Wetland Mitigation Bank have been proposed. We recently completed a study of the seed bank to predict natural establishment of wetland vegetation in the interiors of the restoration bays following closure of the drainage ditches. These data are now being analyzed. Research that examined seedbank and vegetation patterns within and among six functioning, herbaceous Carolina bays has shown that yearly patterns of hydrology influence plant species composition and recruitment from the seedbank. Bays, and areas within bays, that experience fluctuating water levels within a season tend to recruit from the seedbank, be rich in plant species, and lack discrete vegetation zones.

Aquatic invertebrates were studied extensively prior to restoration. We characterized both macro- and micro-invertebrates in three years of bimonthly sampling. We also conducted experimental studies to determine which species persist in resting stages during the dry season and which recolonize when the wetlands are inundated. Initial analyses of these data have been published; further analyses are in progress. 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 support 30-50 species. Lengthening the hydroperiod will generally increase 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 enables us to predict also that herbaceous wetlands will gain more species than the forested wetlands.

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. We planted seedlings of wetland tree species, including cypress (*Taxodium distichum*) and swamp tupelo (*Nyssa biflora*) throughout the forested savanna bays in the winter/spring of 2001. We also planted

two species of wetland grass, maidencane (*Panicum hemitomun*) and leersia (*Leersia hexandra*), in experimental blocks in the herbaceous meadow bays. Monitoring of vegetation development in planted and unplanted areas of the restoration bays will begin in the summer of 2001. The following were accomplished during the past year:

- Prerestoration characterization of the hydrology, soils and biota of the bays to be restored was completed, including their plant and invertebrate communities.
- Initial seed bank studies of the bays, as an indicator of potential natural recovery of the vegetation following restoration was completed.
- Non-wetland trees were harvested and removed from bay interiors and margin treatments were established by appropriate thinning.
- Wetland tree saplings were planted in forested savanna bays and wetland grasses in herbaceous meadow bays.
- Potential mitigation credits were determined and proposed to DOE-SR.

ECOTOXICOLOGY, REMEDIATION, AND RISK ASSESSMENT (ETRRA)

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.

ETRRA'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.*

ETRRA 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.*

ETRRA 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 provides continuing support of 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 reservoirs, waters, and wetlands. By documenting mercury and selected trace metals in fish and other biota over time, and identifying the key watershed processes that control accumulation of metals in biota, land management impacts can be minimized. Field and laboratory studies within this program also explore potential negative effects of ongoing metal exposure on SRS fish and wildlife. Data generated under this program support compliance with state and federal regulations concerning allowable mercury burdens in fish and wildlife. Site activities involving the future of L-Lake or other reservoirs, or Carolina bay restoration, may also alter mercury bioavailability, raising regulatory compliance issues involving the U.S. Environmental Protection Agency and U.S. Fish and Wildlife Service, as well as risk assessment issues. This program closely integrates with the Compliance-Associated 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 increased mercury concentrations in game fish as a result of the Par Pond refill. It has also provided information on mercury in organisms living in Carolina bays, and 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 pisciverous wildlife, including threatened and endangered species such as the Bald Eagle and Wood Stork.

- Analyses of mercury and other heavy metals in prey items used by Bald Eagles and other pisciverous wildlife on the SRS have been completed. These data show that mercury is the major pollutant of concern. Fish from SRS reservoirs, of the size likely to be taken by nesting eagles and fed to their young, have mercury concentrations that exceed current U.S. Fish and Wildlife Service guidelines for sensitive avian species.
- Concentrations of other heavy metals (Cd, Co, Cu, Mn, Ni, Pb, and Zn) in fish from SRS reservoirs do not appear high enough to cause concern to wildlife consumers.
- A study to evaluate the impacts of dietary mercury exposure on a surrogate wading bird species was completed. Snowy Egret nestlings fed a diet based on fish from SRS reservoirs accumulated more mercury than those fed a diet based on fish from an offsite reservoir (Lake Thurmond). Birds fed the higher mercury diet also showed behavioral changes compared to those fed the low mercury diet.
- A manuscript was submitted evaluating risks of mercury exposure to wading birds such as Wood Storks that might forage in Carolina bays on the SRS. Nestlings were at higher risk than adults, and hazards varied among bays.

Monitoring and Risk Assessment for the Endangered Wood Stork

Principal Investigators: Dr. 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.

The Kathwood mitigation ponds were operated in 1999 and monitored to document stork usage. This facility also functioned as a field laboratory determining the variables that affect prey consumption rates of storks. Data from these combined efforts allow for the assessment of environmental risks, associated with past, present, or proposed site activities to wood storks foraging on the SRS.

A new study examining dietary effect of mercury was initiated with a captive population of a surrogate wading bird species (Snowy Egret, *Egretta thula*). This study will document the behavioral and physiological effects, if any, associated with two levels of exposure to dietary mercury (0.1ppm vs. 0.6ppm) found on the SRS. This project, which is ongoing, may provide critical information needed to assess risk to fish-eating avian species and also may allow the determination of the relationships between dietary exposure and tissue mercury burdens in wood storks.

For several years, personnel and other program resources associated with the SREL Wood Stork Program were funded to conduct an in-depth study of the breeding behavior and nesting ecology of the bald eagle (*Haliaeetus levcocephalus*) and the potential risk to this species associated with heavy metal and radionuclide contaminant intake on the SRS. Although no funding is being provided any longer for this work, this past year saw the final analysis of the behavioral and nesting ecology data, along with the completion of the chemical and radiological analyses of dietary items found to be regularly consumed by eagles on the SRS. The results of these contaminant analyses and the associated potential risk to eagles on the SRS will be reported separately in other sections of this annual report.

- In 2000, Wood Stork use of many SRS wetlands as relatively low, due to the continued impact of the long term (2+ years) drought that resulted in the complete drying of many of the wetlands that storks use as foraging habitat. A study examining the effects of the drought on fish populations in Carolina bays is on-going (summer 2001).
- These same drought conditions resulted in a 1-2 meter drop in the Par Pond water level and low numbers (<10) of storks foraged in the shallow portions of the reservoir in mid- to late-fall of 2000. No storks were observed on L-Lake, which is artificially maintained by pumping river water, or in the river swamp system.
- Wood Stork use of the Kathwood mitigation ponds was monitored in 2000 and the continued use of this facility by large numbers of storks was documented. Stork numbers were low to moderate in 2000, presumably due to low reproductive success in the breeding colonies resulting in fewer young birds dispersing to forage in Kathwood. Young-of-the-year storks typically make up a high percentage of the storks using Kathwood. A maximum of 212 storks was observed on a pond in 2000. This (2000) was the final year of DOE funding of the Kathwood site and stork monitoring at this site by SREL will not continue.

Ecotoxicology: Environmental Physiology of Sublethal Effects of Trace Element Contamination on Organisms on the SRS

Principal Investigator: Dr. 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, which provides an aquatic corridor to the river. High levels of trace element contamination (As, Cu, Cr, Cd, Se, Sr) exist in the water, sediments, and biota in the settling basins and downstream areas. Among the organisms that have been documented to be contaminated by trace elements are alligators, softshell turtles, slider turtles, water snakes, largemouth bass, several sunfish, bullfrogs, toads, crayfish, and freshwater clams. This 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 goals of this 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 into nearby terrestrial habitats by birds, mammals, and reptiles. Conditions in D-Area are responsible for the following research findings:

- Four consecutive years of field surveys (1997-2000) revealed that the frequency of spinal malformations in bullfrog larvae developing in the ash basins ranges from 27-38%. The frequency of malformations at the polluted site is up to 30 times higher than what is found in reference sites.
- Water snakes experimentally fed contaminated prey items for two years accumulated high levels of Se, As, Cd, Cu, Sr, and V in liver, kidney, and gonads.
- Water snakes experimentally fed contaminated prey items for two years exhibit histological abnormalities in liver tissue consistent with abnormalities in fish exhibiting Se toxicity.
- Benthic invertebrates, which are an important prey source for benthic feeding fish, accumulate extremely high concentrations of at least 12 toxic trace elements.
- Benthic fish accumulate Se, Cd, As, Sr, V, and Ni when exposed to water, sediments, and invertebrates from the contaminated site. As a result of such accumulation, fish exhibit high mortality and reduced growth rates compared to reference fish.
- Preliminary results on Common Grackles breeding in the contaminated site indicate that they transfer potentially toxic levels of Se to their eggs.

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

Principal Investigators: Domy C. Adriano, Kenneth W. McLeod, Tracy Punshon, Gary Mills, 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) to 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).

- *Crotalaria spectabilis* growth, phenology, and productivity differed as a result of growing in soil containing 0, 5, and 10% fly ash.
- When 10% fly ash was added to potting soils, only Cr concentration of the soil/fly ash mixture was significantly increased, but

Al, B, Cd, Cu, K, Na, Pb, and Zn concentrations were at least 20% higher in the mixture. In spite of the increased concentrations of these potentially harmful elements, height and aboveground biomass of *Crotalaria spectabilis* were not reduced, even when leaf concentrations of Al, B, Cu, and Zn concentrations were increased by at least 20%. None of the leaf concentrations demonstrated increased concentrations ratios (concentration in plant/tissue/concentration in soil) or hyperaccumulator status of this species.

- Addition of 10% fly ash did change the phenology of *Crotalaria spectabilis*, delaying flowering and hence reducing total seed production per plant by 15 and 31% in 5 and 10% fly ash mixtures, respectively. The altered phenology could be due to the differences in elemental composition or water holding capacity of the soil/fly ash mixture. Continued colonization of a fly ash contaminated site by *Crotalaria spectabilis* could be impacted by this reduced seed production.
- 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 phytoextraction 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. Comparison 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.
- Screening studies on *Paspalum* grasses for comparative metal tolerance have also been completed, and have shown that acid-tolerant strains may also have an enhanced ability to tolerate Ni.
- Studies modeling natural attenuation and contaminant bioavailability at Steed Pond indicate that uranium, the main contaminant of concern, is not accumulating within plant tissues and herbivores, but data strongly suggest that there is considerable migration of Ni.
- Scale-up studies using hybrid poplars and black willow at several waste sites will investigate the phytoremediation of inorganic and organic contaminants using the screened poplars in a variety of contaminated soils. Of particular interest is the phytoremediation project at the C-Area burning rubble pit, where dominant indigenous plant species are being screened to evaluate their uptake potential for TCE and its derivatives has been initiated. To date, pines and sweetgum tissues (truck, leaf,

root) were collected for chemical analysis. The concurrent occurrence of titrated groundwater should provide a useful tool as tracer to elucidate on the source term and dynamics of the TCE.

- A workgroup, Natural and Enhanced Environmental Remediation (NEER), at SREL has been initiated under the leadership of Domy Adriano and Lee Newman. The group has met twice for information purposes among professionals at SREL and discussed means on how to collaborate with other research groups at SRS.
- Studies have begun that focus on two sites at the C-area Twin Lakes wetland system. Initial studies aim to establish the role of existing vegetation at two sites with diverse organic contaminant profiles. They will be followed by selective planting of woody phreatophytes to establish whether natural attentuation can be enhanced, or whether it is currently operating at a maximum capacity. Site 1 is situated between the lakes, contains more TCE and less degradation products, whereas Site 2, adjacent to Fourmile Branch represents a more advanced state of natural attentuation of the TCE plume where more degradations products such as vinyl chloride are found. Initial sampling and analysis have detected vinyl chloride in this year's annual rings of both coniferous and broadleaved species at Site 2. Further sampling is currently underway.

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

Principal Investigators: J. D. Congdon and Thomas G. Hinton

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 minimum amounts of mixed wastes that cause detectable abnormalities.

- This multidisciplinary research requires substantial funding due to the expense of the molecular techniques employed to determine effects from contaminant exposure. After developing a molecular technique suitable for determining ecological risks to turtles,

and after making major advances in our outdoor irradiation facility, funds for the research were depleted. Additional proposals to the DOE EMSP program were unsuccessful.

- The frequency of reciprocal translocations in exposed turtles can now be quantified using techniques of polymerase chain reaction (PCR) and flourescent *in situ* hybridization. These techniques are fundamental to our determining what constitutes a significant risk in ecological risk analyses, and will allow us to couple effects observed at the molecular level to those observed in individuals and populations. Four papers were published on the subject in 2001.
- An irradiation facility now exists on the SRS where the effects of waste in combination with radioactive contamination can be tested on aquatic organisms. The unique facility is unlike any other within the United States.
- A paper on the conceptual basis for studies of ecological toxicology (Congdon et al.) was accepted for publication.

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 (^{137}Cs) 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, have been undertaken to study factors controlling the uptake and concentration of these contaminants through controlled/manipulative experimentation. At the same time, assessments of biomarkers indicative of contaminant impacts upon these same animals have been made and this information has then been 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 clean up of contaminated waste sites under Federal Facilities Agreements 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 SRS. 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.

- Radiocesium analyses have been completed

for fish and waterfowl species that figure prominently in the diet of breeding Bald Eagles (*Haliaeetus levcocephalus*) on the SRS. The data from these analyses have been summarized in a draft report which indicates no potential for any significant risk of harm to the eagles from the intake of this contaminant on the SRS.

- A doctoral dissertation has been completed based on a three-year study of the pulation ecology and demographics of the gray fox (*Urocyon cinereoargenteus*) on the SRS. This study has documented an unusually high proportion of older (>34 months) foxes in this unharvested population as compared to offsite populations which are regularly subjected to hunting and trapping. The demographic profile of this population, along with an assessment of the reproduction of foxes on the SRS, suggests that the SRS may serve as a significant source of foxes which disperse offsite into surrounding habitats.
- A major study of radiocesium in fish from the Savannah River adjacent to the SRS has now been published. Only two of six fish species studied from the river showed differences in contamination levels between upstream vs. adjacent vs. downstream locations form the SRS, and one of them was actually more contaminated at the upstream location. No fish from either the river or Steel Creek, an onsite tributary stream, exceeded the radiocesium limit for meat for human consumption as set by the European Economic Community (0.6 Bq/g fresh weight). The consumption of fish from the Savannah River by black male fishermen (the group with the highest consumption rate) showed an estimate of 1.5×10^{-5} for additional lifetime cancer risk associated with the consumption of bass from the Savannah River.
- A manuscript has now been completed and submitted for publication, describing the use of stable isotopes of nitrogen (^{15}N / ^{14}N ratio) to provide a quantitative measure of the trophic feeding position of raccoons (*Procyon lotor*) on the SRS. When location of collection was treated as a co-variable, stable isotope ratios showed significant positive relationships with some trace element concentrations and this isotopic ratio may under appropriate circumstances, help to predict the potential for contaminant concentration by this species, which may on occasion be eaten by humans.

Aquatic Invertebrates and Trophic Pathways for Contaminants in Pond 4, a Small Abandoned Cooling Reservoir on the SRS

Principal Investigator: Barbara E. Taylor

Radiocesium has been an important constituent of the contaminants released accidentally from nuclear reactors. An experiment to study its short-term dynamics in a small impoundment was initiated by T.G. Hinton and J.E. Pinder III (A Field Test of the Efficiency of a Biotic System for Remediating Radionuclide and Metal Contamination in Surface Waters, a DOE Center of Excellence project). Intensive, coordinated sampling programs were designed to track transfers among biotic and abiotic components of the system after stable cesium was introduced into the water of the pond on 1 August 1999. We monitored uptake of stable cesium by the snail *Helisoma trivolvis* and larvae of the insect *Chaoborus punctipennis*.

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. At Pond 4, *Chaoborus* represents planktonic trophic pathways: it feeds on

planktonic microcrustaceans. *Helisoma* represents littoral trophic pathways: it feeds on epiphytic algae and detritus in the littoral zone. Both species are present year-round. Our choices of species were based on extensive quarterly sampling in 1998-1999 to quantify abundances of benthic and planktonic invertebrates (beginning March 1998) and to evaluate trophic position of many common taxa using ratios of stable isotopes of carbon and nitrogen (beginning September 1998). Isotope ratios indicated that closely related species might use different trophic resources and that even the same species might use different resources in different habitats. We thus determined that our inferences about dynamics of cesium would be stronger if we could sample the same species in the same habitats over time. We devised collecting and processing procedures that met this goal and provided biomass sufficient for reliable estimates of the concentration of stable cesium.

The littoral zone encompasses habitats of great structural complexity and intense biological activity. This zone constitutes nearly half of the area of Pond 4. Initial results (eight sampling dates through day 94 of the experiment) point to the importance of littoral processes for the incorporation of cesium into the biota, beginning with the uptake by periphyton.

- Concentrations of cesium in *Helisoma* were an order of magnitude greater than those of *Chaoborus* and five orders of magnitude greater than those of filtered pond water.
- From these initial results, we infer that *Helisoma* and organisms with similar feeding habits may serve as important sources of cesium for their predators, including fish.
- We continued sampling both taxa through day 444 of the experiment; these have been submitted for analysis of cesium concentrations using neutron activation.

Results from experimental additions of cesium to lakes in Canada and Colorado have also suggested that benthic or littoral processes are important in transfers of cesium.

- In contrast with our results for Pond 4, concentrations of cesium were much higher in planktonic invertebrates than in benthic invertebrates at Pond B, another abandoned cooling reservoir on the SRS.
- The samples at Pond B were collected ~20 yr after contaminant input ceased. As the time series of samples from Pond 4 is extended, we will be able to determine whether the two ponds differ in trophic structure or whether the distribution of cesium in the biota changes over time.

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 pressing 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 also essential to the new and revised missions of the DOE at the Savannah River Site and elsewhere, and 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 as one of very few academic institutions deeply 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;*
- *Development of bioindicators as a cost-effective way for assessing risks; and*
- *International programs in radioecology, for transfer of relevant knowledge to address radiation problems at DOE complexes.*

Dose Assessments for Plants and Animals Exposed to Environmental Radiation

Principal Investigators: Thomas G. Hinton,

Travis C. Glenn, and Michael H. Smith

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 clean up 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 clean up requirements or serve to downgrade polluted areas to lower priority or less stringent control measures. The International Atomic Energy Agency and Department of Energy (DOE) have established the maximum allowable doses for aquatic fauna and flora and terrestrial plants (10 milliGray/day) and terrestrial animals (1 milliGray /day). These regulations create a need for accurate determination of dose accrued through internal and external sources of radiation. 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.

- A molecular marker has been successfully developed for assaying the frequency of chromosome damage in turtles. Four manuscripts on the subject were published in 2001.
- An outdoor irradiation facility designed for conducting low-dose experiments is nearing completion. The facility is unlike any in the United States and is a powerful tool for addressing dose-response research.
- A research proposal for $1.2 M was submitted to the DOE Low-Dose program to study adaptive response and genomic instability using molecular tools, transgenic fish, and SREL's outdoor irradiation facility.
- Research proposals to DOE were also submitted for continuation of dose-response work at Chornobyl.

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, John E. Pinder, and Anna C. Knox

The objectives of this research are: (1) to help document current radioactive contaminant levels on the Savannah River Site; (2) to 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 (3) to determine current as well as future human and ecological risks from radioactive contamination. The need for "understanding the transport and fate of contaminants" was specifically recommended as a priority by the National Academy of Sciences in their review of risk assessment within the U.S. Department of Energy (DOE) Environmental Remediation Program. However, with our current state of knowledge it is difficult to understand the dynamics of the contaminants within ecological systems, and therefore, to make predictions about future risks. To reduce the uncertainties, information is needed on site-specific rates of contaminant transfer among environmental

components. Laboratory and field tracer experiments, combined with analytical techniques that identify contaminant speciation, will supply such information. This approach requires concurrent data on the ecological and geochemical aspects of the systems under study. Once the fluxes of contaminants within an ecosystem are quantified, the ability to make informed predictions, with reduced uncertainties, dramatically increases. The following studies were conducted relative to fate and transport questions during the last year:

1) In collaboration with SRTC, we conducted a feasibility study for the phytoimmobilization of uranium, thorium, several of their daughter products, mercury and chromium. These elements are soil contaminants at the TNX Outfall Delta Operable Unit (TNXOU).

- specific species of plants were found to significantly uptake the contaminants, however,
- the annual biomass of plant material was too low to appreciably reduce the contaminant inventory within the soil.

2) A review of historic Pu releases from the SRS was conducted, as well as an evaluation of their environmental transport and dose to humans. The work was published in Plutonium in the Environment, 2001, (Ed.: A. Kudo), Elsevier Science Ltd., UK.

- in agricultural systems, Pu contamination of plants was dominated by the retention of Pu-bearing particles on plant surfaces from direct fallout and subsequent resuspension from contaminated soil, rather than root uptake and translocation within the plant.
- differences in Pu concentrations among crops were due largely to external plant morphologies that affected resuspension of contaminated soil.
- studies in aquatic systems showed that over 99% of the Pu inventory was within the lake sediments.
- doses to humans from Pu releases were found to be less than those acquired from naturally occurring radionuclides or from ^{137}Cs releases.
- maximum dose equivalents (85 uSv) to an individual at the site boundary would have occurred in 1955 and the population dose due to releases that occurred from 1954 to 1989 was 7 person-Sv.

3) A technique for the in situ remediation of ^{137}Cs-contaminated wetlands was deployed for testing in Pond A and the R-discharge canal on the SRS.

- several naturally occurring minerals were tested in the laboratory for their propensity to adsorb and retain ^{137}Cs.
- a candidate remediation mineral was applied to several test cells within Pond A and R-canal at two different treatment levels.
- initial application of the mineral reduced ^{137}Cs concentrations in the water column to below detection limits.
- reduction in ^{137}Cs bioavailability within aquatic plants and fish is ongoing.

International Programs in Radioecology

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

To complement the long history of radioecology research at the SRS, studies at other sites offer opportunities to determine the distribution and behavior of radionuclides in different environments, as well as to evaluate the effects of higher radiation doses on resident organisms. The high levels of environmental radiation at Chornobyl offer unique opportunities for important investigations that can assist in strategic planning in case of future accidents or releases, assess the effectiveness of cleanup technologies, and evaluate the risks associated

with chronic exposure to radiation. SREL scientists have been involved with research at Chornobyl and other sites in the former Soviet Union since 1992 and have developed excellent working relationships with foreign scientists and administrators. Our efforts to strengthen working relationships with the scientists at Chornobyl have resulted in the establishment of the International Radioecology Laboratory (IRL) in Slavutych and Chornobyl, Ukraine. The IRL was established by two separate agreements: the Government to Government Agreement signed on 22 July 1998 during the summit conference of Vice President Gore and Ukrainian President Kuchma and the Agreement between the University of Georgia and the Chornobyl 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 Chornobyl 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. Continuance of funding for the operation of the IRL has been a major area of effort, as well as initiating high-quality research programs in concert with scientists from the University of Georgia, University of South Carolina, and Texas Tech University. One project tests the hypothesis that radioactive contamination altered genetic diversity and developmental stability in populations of small mammals in areas near Chornobyl using yellow-necked mice (*Apodemus flavicollis*) as a model species. These studies will be a part of a doctoral dissertation by a native Ukrainian student at SREL (Taras Oleksyk). Another project examines radioactivity, genetic, and morphological variation in plants including *Typha latifolia*, *T. angustifolia* and *Betula verucosa* collected near Chornobyl as well as reference sites. A study of the distribution and effects of radionuclides on plants will be part of a doctoral dissertation of another native Ukrainian student at SREL (Olga Tsyusko). A third project measures radioactivity in fish, amphibians and mammals from the Chornobyl area and the SRS to examine the frequency distributions of ^{137}Cs in populations. These frequency distributions are non-normal, as indicated by strong relationships between standard deviations and means. The shape of radionuclide frequency distributions are critical to designing appropriate sampling strategies, and in developing risk assessment models. New studies have also been initiated on radionuclide accumulation and effects in amphibians from contaminated wetlands.

- Two manuscripts were accepted for publication describing the frequency distributions of radiocesium in populations of terrestrial and aquatic animals. The frequency distributions of these contaminants were non-normal and skewed, demonstrating that the highest concentrations and thus the greatest risks are confined to relatively few individuals in each population.
- Radiocesium measurements were completed on several species of amphibians collected near Chornobyl. Frogs of the species *Rana terrestris* contained nearly twice as much radiocesium than *Rana esculenta* from the

same area; this may reflect differences in diet between the species.

- Measurements were completed on radionuclide concentration and genetic diversity in rodents collected near Chornobyl and in reference areas. Genetic diversity in multiple reference populations was assessed to determine variability in natural populations, and then compared to affected populations. There were significant differences among populations in genetic diversity, including increased variability from north to south. Tissue radiocesium and individual microsatellite variability were correlated in rodent populations. However, these correlations did not represent a consistent trend and varied from population to population. Higher levels of fluctuating asymmetry, a measure of developmental stress, occurred in rodent populations in close proximity to Chornobyl.

Papers, abstracts and presentations generated by this program in the past year:

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Genetic Changes in Response to Previous and Current Plant Operations

Principal Investigators: Michael H. Smith, Travis C. Glenn, Charles H. Jagoe, J Vaun McArthur, and Christopher S. Romanek

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 organisms' exposure levels to the contaminants; (3) determine the relationships between the effects in the organisms and the levels of the contaminants, 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, developmental biology, and risk assessment. These techniques are used in both laboratory and field experiments as well as field surveys. The primary focus is on flora and fauna from SRS sites, but we are increasing activities in the assessment of microbial communities. 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 Chornobyl). Thus, our broader goal is to address applied problems with solutions that are based upon a solid theoretical and scientific basis. We are using markers of genetic variation including mitochondrial DNA, anonymous nuclear DNA, and microsatellites as well as measures of DNA damage including strand breakage assessed using pulsed field gel electrophoresis and single cell (also known as "comet") assays. We are comparing measures of genetic variation or DNA damage to traditional measures of contamination (concentrations of radionuclides, heavy metals and/or organics), morphology (e.g., size of skeletal elements, length, weight, and asymmetry), and physical condition (e.g., body fat and presence of tumors). We are examining comparisons within and among wildlife populations and other model organisms to determine the relationships among these variables.

We have completed several tasks during this last year:

- Studies of DNA strand breakage in several species of fish and amphibians are ongoing. Initial results indicate that the levels of DNA strand breakage among vertebrates from most SRS locations are not significantly higher than most reference locations.
- Studies of the genetic effects of heavy metals on microbial communities were initiated. Preliminary results indicate high levels of microbial diversity, but potential selection for specific heavy metal genes that correlate with the level of heavy metal in the environment.
- A study showing the patterns of mitochondrial DNA variation among American alligator populations was submitted

for publication in the Journal of Herpetology. This study shows that mitochondrial DNA among SRS alligators is not significantly different from other alligator populations.

- Levels of ^{137}Cs in American alligator eggs and hatchlings from Par Pond, Pond B, and Beaver Dam Creek were determined. These results are being integrated into a study of radionuclide and heavy metal contaminants and mutation rates among populations of American alligators, focusing on the PAR Pond population at the SRS.

CENTERS OF EXCELLENCE

The Savannah River Ecology Laboratory (SREL) played a pivotal role in the development of the U.S. Department of Energy-Savannah River Environmental Centers of Excellence Program at the Savannah River Site. Participants in these centers include the Savannah River Ecology Laboratory (SREL), Education, Research and Development Association of Georgia Universities (ERDA), and South Carolina Universities Research and Education Foundation (SCUREF). In 1997 SREL received funding for six collaborative research projects. Project descriptions and accomplishments for programs completed during FY01 are detailed on the following pages.

Experimental Approach to Constructed Treatment Wetland Design

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

Constructed treatment wetlands can effectively remediate acidic-sulfate water such as leachate from coal storage piles and from mine tailings. On the Savannah River Site, coal-pile run-off from the D-Area power plant is collected in a shallow basin (the D-Area Basin) and contaminates shallow groundwater in the area. Water in the D-Area Basin is acidic (pH of about 2.5) and high in dissolved metals including iron (Fe), aluminum (Al), copper (Cu), zinc (Zn), nickel (Ni), manganese (Mn), and chromium (Cr).

The overall objective of this research was to determine the feasibility of using constructed passive treatment wetlands to improve the quality of acid-sulfate water such as the drainage from the D-Area basin. Specific goals of the experiment were: 1) to understand the process of acid-sulfate remediation, and 2) to test the effectiveness of wetland substrate, plant community composition, and different microbial assemblages in improving water quality.

An experimental mesocosm array of 16 wetland treatment systems was established adjacent to the D-Area basin. Each experimental wetland consisted of three linked mesocosm cells: an anaerobic cell designed to raise the pH of the water and lower metal concentrations and two aerobic cells designed to further reduce metal concentrations. Thus, in each experimental system water from the basin flowed first through an anaerobic cell filled with organic substrate and limestone, and then through two aerobic cells representing deep and shallow wetlands. The order of deep and shallow aerobic cells, and their vegetation composition (planted with native plants, planted with artificial plants to provide substrate for microbial assemblages, not planted) were varied to test site-specific effectiveness of many component combinations. The treatment began in the spring of 1999 and was terminated in the late fall of 2000, following two growing seasons. Major findings included:

- In the anaerobic mesocosm cells, Fe, Al, Cu, Zn, and Ni showed trends of accumulation over time. Approximately 98% of the Fe and 99.9% of Al were removed as oxyhydroxides, sulfides, and carbonates. The latter two of these solids were formed either directly or indirectly as a result of biomediated sulfate reduction reactions. Manganese was the only metal examined that did not accumulate in the anaerobic cells.
- Across all treatments, the aerobic wetland cells had a further positive effect on remediation of the acidic drainage by removing from 0.5% to 1% of the initial Cu, Fe, and Ni and 50% of the Mn. Final pH levels of water passing through the treatment mesocosms ranged from about 6.3 to 7.3.
- The five native wetland plant species differed in their nutrient and metal accumulations. In general, highest metal accumulation by most species occurred in root or rhizome tissues. The exception was Mn, which showed highest accumulation in shoot tissues. The native plants showed promise for use in a polishing system to remediate metal contaminated waters.

A Field Test of the Efficiency of a Biotic System for Remediating Radionuclide and Metal Contamination in Surface Waters

Principal Investigators: Thomas G. Hinton, John E. Pinder and Christopher S. Romanek.

An experimental tracer study using stable nonradioactive cesium (^{133}Cs) additions to an entire pond is underway. The data will yield valuable kinetic transport information on the rate that Cs migrates through aquatic systems. Such data are critical for evaluating the long-term movement of radioactive Cs, and in predicting the associated risks to offsite residents. The data also test the concept of monitored natural attenuation for a radioactive contaminant.

We have been routinely sampling water, sediments, plankton, fish, macrophytes, invertebrates, and periphyton to determine the rate the added stable Cs moves from one environmental component to another.

- After the initial addition, the decline in Cs concentrations within in the water could be described by a three-component exponential model, with long-term loss rates amounting to about 1% per day.
- Concentrations of Cs in plankton, snails and macrophytes were several orders of magnitude greater than concentrations in the water.
- ^{137}Cs within the sediments of the pond were remobilized after the addition of the stable Cs, and increased by a factor of three.
- The dynamics of stable Cs uptake by macrophytes varied significantly among plant species.

An associated experiment is examining Cs dynamics between water and sediment at four different scales. In addition to the whole-lake experiment, two smaller- scaled limnocorrals and one laboratory-based experiment are being conducted. The smaller-scaled experiments use water and sediments from pond 4 to see if the rate at which stable Cs leaves the water column is similar to that measured in the whole-lake experiment. If so, future experiments could be greatly facilitated and with improved replication by using experimental units of smaller scale than the entire pond. The question of what is an appropriately scaled model is fundamental to most of science.

Enhanced Degradation of Halogenated Organic Contaminants Using Redox-Manipulated Aquifer Material and Iron-Bearing Clays

Principal Investigators: Gary Mills and Valentine Nzengung (University of Georgia)

This project evaluates the feasibility of creating an in-situ permeable barrier by chemical reduction of redox sensitive metals (Fe, Mn) within aquifer sediments which will degrade perchloroethylene (PCE) and trichloroethylene (TCE) contaminants in groundwater plumes. Laboratory studies using batch-reactors are being employed to determine degradation kinetics and to identify reaction products on various clay minerals, metal oxide and aquifer sediments. Dynamic column experiments were used to evaluate the
longevity of chemically-reducing conditions in SRS aquifer sediments after reduction with sodium dithionite. Reaction rates and pathways were also determined for naturally-reduced sediments associated with floodplain soils to establish the efficiency of natural attenuation of PCE and TCE in the seep zones where contaminated groundwater may outcrop near surface streams. These studies will assist in selecting and implementing new remediation strategies to treat more highly contaminated plumes as well as provide predictive models for assessing the natural attenuation

processes that serve to remove contaminants in ground waters.

Our previous studies indicated that using the treatment protocols for in-situ redox manipulation (ISRM) developed for the Hanford site, 90% of the total iron was removed from the reduced SRS sediment column after the pulsed input of PCE contaminated ground water. These results indicated serious problems are likely in deploying this remediation technology at SRS field sites without modification of the treatment conditions. During the past year, we have modified the reduction protocol to nearly eliminate the flux of iron from the chemically reduced sediments. The results from our column studies indicates that using the modified protocol the ISRM technology is effective for remediating Cr(VI) but not PCE or TCE in typical Atlantic Coastal Plain Aquifers.

Research Support Programs

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

Environmental Outreach and Education

J. Whitfield Gibbons

The Savannah River Ecology Laboratory's twin missions of research and outreach 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 businessmen. No program exemplifies this better than the herpetology program.

The southeastern United States has the highest biodiversity and abundance of reptile and amphibian species in North America. Because of the rich herpetofaunal biodiversity on the Savannah River Site (SRS), this public land area has been the focus of extensive inventory and research since 1951 and has become the most prolific single site for herpetological research in the world. 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, resulting in the documentation of more species of herpetofauna (1,000,000+ individuals of 100+ species) than reported from any other public land area in the United States.

SREL uses this information not only to further research efforts, but also to educate the public, both locally and nationally. For while the goal of current studies is to capitalize on this enormous data base and continue to add sound data to it, this is not being done in an academic vacuum. The environmental commitments of SREL extends beyond the lab, the SRS, and even the larger local area. Issues as diverse as amphibian and reptile population declines, potential responses (e.g., mutations) 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. At no time has this been more clear than in 2001. Based on research and analysis done at SREL, a global trend of reptile declines has been documented and published in the scientific literature.

The SRS is one of the most highly diverse tracts of land in the Upper Coastal Plain as a consequence of long-term environmental protection of native habitats. Studies done here serve to confirm the assumption that environmental health on the SRS is high in comparison to surrounding regions, as well as having direct applicability to the Endangered Species Act, the site initiative of environmental cleanup, and to DOE Land Use and Facilities Management Policies and environmental stewardship. Due to this unique protected environment, ecological research here, especially on the herpetofauna, has taken place under well-controlled conditions and over long periods of time. Recognition for the laboratory's outstanding work has come from many sources.

SREL has been selected and funded by 10 federal agencies to operate the Partners in Amphibian and Reptile Conservation (PARC) national Web site (www.parcplace.org), which will serve as the nexus for herpetofaunal databases throughout the country.

More than 40,000 copies of "Snakes of Georgia and South Carolina" have been distributed, all paid for by outside sponsors in the private sector as well as state and federal agencies.

The herpetology website (http://www.uga.edu/srelherp/) continues to be developed and refined. This site has been visited by

more than 47,000 viewers and has generated numerous queries from interested individuals.
The monitoring of Rainbow Bay reptiles and amphibians continued for its 23rd year, as recommended by the SRS Citizens Advisory Board.
Increased demand for Outreach speakers have required greater use of the Distance Learning Facility.

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:

(1) School groups enjoy field trips to the Laboratory's Conference Center and speakers from SREL go to schools, presenting messages of conservation, remediation, andenvironmental stewardship.
(2) Teachers are trained in methods of teaching ecology during workshops and leave with materials produced by the Outreach staff.
(3) Speakers from SREL are in such demand that the SREL Distance Learning Facility has been pressed into service to serve more classrooms.
(4) An internal laboratory newsletter, The GrapeVine, is distributed electronically and an external newsletter, SREL Ecolines, is published quarterly and mailed.
(5) During the past year, SREL scheduled 216 talks, 52 tours, 19 exhibits, and 30 workshops, for a total of 77,000 people reached. Topics for these presentations included biodiversity, animal adaptation, plants and wetlands, local ecosystems and conservation, classification, and careers in ecology and research. The education functions of the lab have been consolidated with the outreach group.
(6) The SREL publication "An Amphibian's Eye View of Wetlands" was honored with an Award of Distinction from The Communicator Awards. Over 10,000 copies of this popular flier have been distributed this year through SREL's Outreach Program and the National Audubon Society's Wetlands Campaign.
(7) 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. "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. Other presentations offered include tours of the Lab and surrounding field sites, exhibits, and workshops offered to the general public. A 27-minute six-projector automated slide presentation about the history of the SRS and SREL research continues to be a regular part of SREL tours.

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 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. New publications produced this past year included the flier on "An Amphibian's Eye View of Wetlands," produced in cooperation with the National Audubon Society; a children's comic book entitled "Stepping into Ecology: the Ecological Adventures of Mud E. Boot," produced in cooperation with the Medical University of South Carolina's Environmental Biosciences Program; a flier on "Is it a Water Moccasin?" produced in partnership with the Georgia Department of Natural Resources Nongame-Endangered Wildlife Program; 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 products have been extremely popular and thousands of copies have been distributed during the past year.

The public relations 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 Pubic Relations office screens most inquiries from the press, directing reporters to the most helpful researchers for their stories. In addition, SREL initiates press contacts, such as the annual Eco-Calendar, 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 has also provided an opportunity for speakers from the Lab to address groups at Fort Discovery.

The Outreach program continues to produce and distribute various publications: Outdoor Classroom Planning Guide, Biodiversity: Prospect & Promise for the Savannah River Site, The National Environmental Research Park at Savannah River Site: Serving an Essential Mission for 25 Years, and Snakes of Georgia and South Carolina, in addition to new products. The Guide gives instructions for setting up a variety of outdoor classroom stations and outlines activities and investigations which 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. Also, a series of full-color fact cards is produced and distributed. Full-color fact sheets are published on a variety of subjects as well.

The 1998 publication, "Snakes of Georgia and South Carolina," serves as an identification guide to all snakes of the region as well as providing information on snake safety. In the two years since its publication, its popularity has grown and necessitated three printings. The demand for the book has grown with each printing 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. It was 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.

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 base.

Previously, NERP initiatives changed annually as directed from DOE in Washington, D.C. However, the final disposition of the NERP program has now fallen to local DOE sites because the program is presently not supported nationally by DOE' s Office of Science. In recent years, the SRS NERP program has been supported with funding from within the SREL budget. During the past year, however, for the third year in a row, no funding was available to support specific NERP objectives and activities. Thus, at this point at least, the NERP concept at the SRS has become a conceptual framework for the development of environmental research activities on the SRS site lands, but without specific program activities being funded or conducted in this area at this time. A webpage was developed based on a poster presented at the 50th Biological and Environmental Research (BER) in 1997. This webpage is viewable at www.uga.edu/srel/projects.htm and is the basis for a website developed by Oak Ridge National Laboratories.

During the past year, although no specific funding was made available for the site NERP activities, the SRS site NERP Coordinator (I.L. Brisbin) was able to make a number of presentations concerning NERP program goals and objectives at the SRS, to a number of groups throughout the southeast. Theses presentations, which also emphasized the need to eventually introduce congressional legislation officially defining and designating the SRS as a National Environmental Research Park, were made to groups such as the Columbia, SC chapter of the Sierra Club and the Charleston (SC) Natural History (Audubon) Society. In most cases, travel expenses associated with those presentations were provided by the groups to whom the presentations were made.

Two particularly important presentations that were made in this regard were invited plenary addresses given at the statewide workshops of both the Georgia and South Carolina Interfaith Climate Change Initiatives of the National Council of Churches. These presentations described the importance of the large protected areas of natural habitat, as locations for testing critical landscape-level hypotheses concerning carbon sequestration

and global warming. The important role that sites such as the SRS NERP could play in national programs of global warming research was thus clearly emphasized.

Environmental Health and Safety Program

Warren J. Safter and Donald R. Mosser

The Savannah River Ecology Laboratory (SREL) has completed its fourth year of operation under the work-smart safety and environmental standards which resulted from SREL's participation in U.S. Department of Energy's (DOE) Necessary and Sufficient process. These standards appropriately address the hazards associated with SREL operations by permitting a focused effort on the health and safety issues most pertinent to SREL operations.

In an effort to increase the efficiency and effectiveness of the Environmental Health and Safety (EH&S) Program, a greater emphasis continues to be placed on safety and environmental training of SREL personnel. It is generally well accepted that a well-trained and educated workforce will result in fewer on-the-job injuries and environmental mishaps. New personnel safety and environmental orientation and University of Georgia Right-to-Know training was presented to 56 individuals. Additionally, training was provided for Chemical Coordinators, hazardous waste workers, and radioactive sealed source users. Chemical Specific Right-to-Know training was provided to all individuals who work with hazardous chemicals. In addition, specialty training in the use of fire extinguishers, compressed gas safety, driver safety, bloodbourne pathogens, ergonomics, respirator use, electrical safety in the laboratory, and personal safety (self-defense) for women were provided for SREL personnel.

On a more informal level of training, the use of SREL's internal computer network to provide targeted information to specific groups in the laboratory and extensive use of World Wide Web and Internet resources brought pertinent information to the attention of SREL personnel. More than 100 lessons learned and health and safety topics were distributed via email throughout the year. Safety training literature is also placed in the break rooms and pamphlets are made available in the hallway magazine rack.

Facility inspections remain a cornerstone of the SREL Safety Program. In addition to regularly scheduled inspections by SREL personnel, The University of Georgia has conducted fire safety and laboratory safety inspections. In addition, DOE conducted a comprehensive industrial hygiene assessment of SREL operations and EPA and SCDHEC conducted an inspection of SREL hazardous waste management areas. DOE has also conducted a workplace safety walkthrough and routinely inspects SREL facilities. DOE also conducted an ISO 14001 audit of SREL's Environmental Management Program and SREL's ISO 14001 program was recertified for an additional three-year period. In summary, SREL has performed remarkably well in all of these inspections and assessments.

The issue regarding improper transportation of radioactive samples from Chornobyl during FY 2000 was resolved favorably earlier this year. There were no serious repercussions from the Price Anderson investigation nor from the investigations conducted by the U.S. Department of Transportation or the Federal Aviation Administration. Although SREL was cited by these organizations for improper transport, no fines were assessed nor was disciplinary action taken against SREL. All internal corrective actions relating to this matter have been accomplished.

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 as a means of reducing the burden associated with current waste disposal procedures have been incorporated into experimental protocols, providing greater environmental protection while reducing bureaucratic overhead. SREL disposed of a significant quantity of hazardous and radioactive waste this year.

As downsizing of SREL support personnel continues, the EH&S Program has assumed additional responsibilities this year for the ISO 14000 environmental program, emphasizing the need for continued program efficiency and effectiveness. Objectives for SREL EH&S have been included in the SREL Strategic Plan.

Distance Learning Program

Laura Janecek

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 more than 350 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 (DLP) continued to focus its efforts on programming related to SREL core programs in ecology and environmental science and provided almost 700 hours of programming to SREL and SRS personnel. The primary program for SREL is the multidisciplinary 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. Five new students are expected to begin the program in the fall of 2001, in addition to five students continuing into the second year of coursework for the degree. Three students have completed all required coursework and are working on the research component of the degree.

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 12 lectures on various ecological topics to students in South Carolina and Georgia's K-12 schools. Topics included:

- Reptiles and Amphibians of the Southeast
- Carolina Bays
- Keeping Track of Wood Storks
- Life in Wetlands

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. A booklet providing guidance to SREL researchers, titled "SREL Good Research Practices," was written and is distributed to all new SREL research personnel. This booklet discusses research concepts and context, researches logistics, and the conduct of research.

Research Data Archive Activities

Laura Janecek

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 FY '01 and the Central Archive Data Repository now has information covering over 600 separate studies.

The current SREL database catalog, ARCHCAT, is a DOS-based program and is outmoded. During the past year we have been developing a new Windows-based catalog. This new data base, SAD (SREL Archive Database), will use Microsoft Access and will allow users to submit both their metadata and data files via the SREL Intranet as well as view the all metadata entries in SAD. We anticipate that SAD will be implemented during the spring of 2002.

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 provides for a diverse and protected outdoor laboratory where researchers study the environmental impacts of the Site's industrial and forest management operations. Because these studies are often 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 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, aids in the maintenance of a high degree of biological diversity on the SRS, and enables DOE-SR to meet the objectives of the NERP Program. Currently, there are 30 Set-Aside Areas on the SRS that collectively account for 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 89 timber resource compartments that comprise the SRS. There are approximately 270 miles (168 km) of posted boundary line associated with these Set-Aside Areas.

Maintenance of the Set-Aside Areas

The Set-Aside Program is administered by the Savannah River Ecology Laboratory (SREL) and overseen by a six-member Set-Aside Task Group comprised of natural resource experts from the Westinghouse Savannah River Company (WSRC), the U.S. Forest Service-Savannah River (USFS-SR), South Carolina Department of Natural Resources (SCDNR), 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 the Set-Asides Areas. 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. Periodic inspections of Set-Aside boundary postings continue to be conducted by SREL where potential land-use conflicts are anticipated. 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 is being 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-FS continually monitor any potential pine beetle problems in Set-Aside Areas and 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, as a working coverage, is made available to USFS-SR timber and GIS personnel for timber stand updating. To date, a significant portion of this boundary layer has been modified as the result of the USFS-SR GPSing timber sale boundaries and the availability of better rectified photography to use for boundary delineation A total of six Set-Aside Areas and a large portion of Reedy Branch (E. P. Odum Wetland) have been GPSd entirely. A new release of this GIS boundary data layer is anticipated in FY02 for the general site to use in land use planning.

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 the Set-Aside Area management plans. Because of this responsibility, this person serves 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 coordination and planning with the USFS-SR is successful in verifying Set-Aside and timber stand boundary line concordance with GIS coverages, updating TES population surveys conducted in Set-Aside Areas, and in addressing potential conflicts with forestry activities adjacent to Set-Asides and SREL research areas. Recent focus has been on developing timber management plans for the Site's subwatersheds, 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 plans with prescribed treatments, if any, are generally developed by a core team of individuals from the various Site organizations. 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 will have its own assumptions, guidelines, and desired future conditions. 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 that are addressed include TES flora and fauna, boundary line maintenance, fire suppression, and clean up of research sites. As these natural resource plans are

formulated, SREL and USFS-SR negotiate, if needed, 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.

During the past year, SREL worked on the development of management plans for five Set-Aside Areas, three of which were completed for the USFS-SR's timber compartment 11. Compartment 11's resource prescriptions were renewed in this FY and management plans for the Sandhills (Area No. 3), Dry Bay (Area No. 23), and Field 3-409 (Area No. 28) were completed and incorporated into these prescriptions. Recommendations from these plans resulted in a 40 acre increase in critical habitat for the Sandhills Set-Aside and a 7 acre reduction for the Field 3-409 Set-Aside. In addition, GIS work was completed for the development of management plans for the Society of American Forester's (SAF) Boiling Springs and Scrub Oak Natural Areas (Area Nos.18 and 29). Stand boundaries for a 30-acre pine thinning treatment in the Flamingo Bay Set-Aside were flagged and the unit awaits marking for timber sale to begin implementation of this Set-Aside's management plan. This year, discussions continued as part of the conservation easement agreement between Chem Nuclear and DOE, resulting in an agreement that USFS-SR and SREL will work together to develop a fire management plan for the Chem Nuclear's portion of Craig Pond that will not impact SREL's research in the Craig Pond Set-Aside.

Research in Set-Aside Areas

Researchers from SREL continued numerous long-term plant and animal studies in Set-Asides including: aquatic macroinvertebrate studies in Upper Three Runs Creek; a genetics study looking at variation over a small mammal species' range; daily amphibian population monitoring at Rainbow Bay; continued use of animals from Risher Pond and Ginger's Bay as controls for D-Area studies; monitoring of turtle nesting and predation; studies of the reproductive behavior of frogs; and an amphibian monitoring program based on calls at Ellenton Bay. In addition, Carolina bay Set-Asides continue to be used as proxies in studies of the hydrology of man-made catchment basins; these studies will support future 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. Also, several wetland plant and seed bank characterization studies in Set-Asides were concluded and published this fiscal year.

New studies initiated this fiscal year where Set-Asides were used include: tropic transfer of heavy metals; dispersal of amphibians from an ephemeral wetland (Ginger's Bay); and a soil nitrogen and plant organic uptake study.

Groups other than SREL also continue to use the Set-Aside Areas. STRC 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 bioassessment protocols at DOE sites. SRARP researchers 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 in the field of conservation biology to help manage and protect these unique wetlands. There are a number of publications this year where the Meyers Branch Set-Aside is the reference stream for the Pen Branch wetland restoration studies. In addition, the USFS-SR and

SREL continued to use Set-Aside Areas in their environmental education and outreach programs.

Additional resource management efforts

During the past year, SREL's Set-Aside research coordinator continued updating SREL's Carolina bay GIS coverage based upon interpretations of 1951 and 1998 photography. In addition, a GIS layer for historical ditches on the SRS was updated for determining historical wetland hydrology impacts and for future restoration purposes. Although these are working draft coverages and they have not been officially released, they are used by the USFS-SR for making wetland restoration decisions and for developing resource prescriptions for the timber compartments. The stewardship management plan for the Conference Center property was approved by SREL with the condition that habitat manipulation modifications recommended by the Outreach Program be accepted. Also, an SREL Site-Use Permit GIS layer continued to be updated to provide maps for land use coordination and for conducting ecolitter evaluations. In addition, SREL's Site-Use permitted research site database for tracking ecolitter cleanup evaluations was updated and proved vital to a successful ISO 14001 audit conducted this year for SREL.

Although the Set-Aside Program is no longer able to support student research grants, 39 papers were published this year that used habitats or organisms associated with a Set-Aside. Based on SREL's list of publications, 18 of the Set-Aside Areas had recent published research associated with them this fiscal year.

Recent SREL publications, theses, and dissertations that used Set-Aside Areas:

Barton, C., E. A. Nelson, R. K. Kolka, K. W. McLeod, W. H. Conner, M. Lakly, D. Martin, J. Wigginton, C. C. Trettin, and J. Wisniewski. 2000. Restoration of a severely impacted riparian wetland system - The Pen Branch Project. Ecological Engineering 15:S3-S15.

Brady, M.J., T.S. Risch, F.S. Dobson. 2000. Availability of nest sites does not limit population size of southern flying squirrels. Canadian Journal of Zoology 78:1144-1149.

Bryan, A. L., Jr., M. C. Coulter, and I. L. Brisbin, Jr. 2000. Mitigation for the endangered wood stork on Savannah River Site. Studies in Avian Biology 21:50-56.

Buhlmann, K. A. 1998. Ecology, Terrestrial habitat use, and conservation of a freshwater turtle assemblage inhabiting a seasonally fluctuating wetland with emphasis on the life history of *Deirochelys reticularia*. Ph.D Dissertation. University of Georgia. Athens, Georgia.

Burke, V. J., J. E. Lovich, and J. W. Gibbons. 2000. Conservation of freshwater turtles. p.156-179. *In* Turtle Conservation, edited by M. Klemens. Smithsonian Institution Press, Washington, DC.

Collins, B., P. S. White, and D. W. Imm. 2001. Introduction to ecology and management of rare plants of the southeast. Natural Areas Journal 21:4-11.

Edwards, A.L., and R.R. Sharitz. 2000. Population genetics of two rare perennials in isolated wetlands: *Sagittaria isoetiformis* and *S. teres* (Alismataceae). American Journal of Botany 87:1147-1158.

Edwards, A. L., and A. S. Weakley. 2001. Population biology and management of rare plants in depression wetlands of the southeastern coastal plain, USA. Natural Areas Journal 21:12-35.

Gibbons, J. W., D.E. Scott, T.J. Ryan, K. A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C. Winne. 2000. The global decline of reptiles, Déjà Vu amphibians. BioScience 50:653-666.

Fletcher, D. E., S. D. Wilkins, J V. McArthur, and G.

K. Meffe. 2000. Influence of riparian alteration on canopy coverage and macrophyte abundance in Southeastern USA blackwater streams. Ecological Engineering 15:S67-S78.

Gaiser, E. E. and J. Johansen. 2000. Freshwater diatoms from Carolina Bays and other isolated wetlands on the Atlantic Coastal Plain of South Carolina, U.S.A., with descriptions of seven taxa new to science. Diatom Research 15:75-130.

Giese, L. A., W. M. Aust, C. C. Trettin, and R. K. Kolka. 2000. Spatial and temporal patterns of carbon storage and species richness in three South Carolina coastal plain riparian forests. Ecological Engineering 15:S157-170.

Hartman, G. D., J. O. Whitaker, Jr., and J. R. Munsee. 2000. Diet of the mole *Scalopus aquaticus* from the coastal plain region of South Carolina. American Midland Naturalist 144:342-351.

Hinton, T. G., and J. E. Pinder, III. 2001. A review of plutonium releases from the Savannah River Site, subsequent behavior within terrestrial and aquatic environments and the resulting dose to humans. p. 413-435. *In* Proceedings of the Second International Symposium Plutonium in the Environment, edited by A. Kudo. Elsevier, Kyoto University, Osaka, Japan.

Imm, D. W., H. E. Shealy, Jr., K. W. McLeod, and B. Collins. 2001. Rare plants of southeastern hardwood forests and the role of predictive modeling. Natural Areas Journal 21:36-49.

Kennamer, R. A., and G. R. Hepp. 2000. Integration of research with long-term monitoring: breeding wood ducks on the Savannah River Site. Studies in Avian Biology 21:39-49.

Kilgo, J. C., K. E. Franzreb, S.A. Gauthreaux, Jr., K. V. Miller, and B. R. Chapman. 2000. Effects of long-term forest management on a regional avifauna. Studies in Avian Biology 21:81-86.

Koetsier, P., and J. V McArthur. 2000. Organic matter retention by macrophyte beds in 2 southeastern USA, low-gradient, headwater streams. Journal of the North American Benthological Society 19:633-647.

Kolka, R. K., J. H. Singer, C. R. Coppock, W. P. Casey, and C. C. Trettin. 2000. Influence of restoration and succession on bottomland hardwood hydrology. Ecological Engineering 15:S131-140.

Kreher, S. A., S. A. Foré, and B. S. Collins. 2000. Genetic variation within and among patches of the clonal species, *Vaccinium stamineum* L. Molecular Ecology 9:247-1252.

Lakly, M. B., and J V. McArthur. 2000. Macroinvertebrate recovery of a post-thermal stream: habitat structure and biotic function. Ecological Engineering 15:S87-S100.

McArthur, J. V., and R. C. Tuckfield. 2000. Spatial patterns in antibiotic resistance among stream bacteria: effects of industrial pollution. Applied and Environmental Microbiology 66:3722-3726.

Medland, V. L., and B. E. Taylor. 2001. Strategies of emergence from diapause for cyclopoid copepods in a temporary pond. Arch. Hydrobiol. 150:329-349.

Meyers, M. J. and E. P. Odum. 2000. Early avian research at the Savannah River Site: Historical highlights and possibilities for the future.Studies in Avian Biology 21:18-31.

Miller, S. P., and R. R. Sharitz. 2000. Manipulation of flooding and arbuscular mycorrhiza formation influences growth and nutrition of two semiaquatic grass species. Functional Ecology 14:738-748.

Paller M. H., M. J. M. Reichert, J. M. Dean. And J. C. Seigle. 2000. Use of fish community data to evaluate restoration success of a riparian stream. Ecological Engineering 15:S171-187.

Pechmann, J. H. K., R. A. Estes, D. E. Scott, and J. W. Gibbons. 2001. Amphibian colonization and use of ponds created for trial mitigation of wetland loss. Wetlands 21:93-111.

Ryan, T. J., and C. T. Winne. 2000. Effects of hydroperiod on metamorphosis in Rana sphenocephala. American Midland Naturalist 145:46-53.

Ryan, T.J. and W. A. Hopkins. 2000. Interaction of sex and size and the standard metabolic rate of paedomorphic *Ambystoma talpoideum:* Size does matter. Copeia 3:808-812.

Rowe, C. L., W. A. Hopkins, and V. R. Coffman. 2001. Failed recruitment of southern toads (*Bufo terrestris*) in a trace element-contaminated breeding habitat: direct and indirect effects that may lead to a local population sink. Archives of Environmental Contamination and Toxicology 40:399-405.

Sever, D.M., T.J. Ryan, T. Morris, D. Patton, and S. Swafford. 2000. Ultrastructure of the reproductive system of the black swamp snake *(Seminatrix pygaea)*: Part II. annual oviducal cycle. Journal of Morphology 245:146-160.

Snodgrass, J.W., A.L. Bryan, Jr., and J. Burger. 2000. Development of expectations of larval amphibian assemblage structure in southeastern depression wetlands. Ecological Applications 10:1219-1229.

Tatara, C. P., M. C. Newman, and M. Mulvey. 2001. Effect of mercury and *Gpi-2* genotype on standard metabolic rate of eastern mosquitofish (*Gambusia holbrooki*). Environmental Toxicology and Chemistry 20:782-786.

Voelz, N. J., and J V. McArthur. 2000. An exploration of factors influencing lotic insect species richness. Biodiversity and Conservation 9:1543-1570.

White, D. L. and K. F. Gaines. 2000. The Savannah River Site: Site description, land use and management history. Studies in Avian Biology 21:8-17.

Wigginton, J. D., B. G. Lockaby, and C. C. Trettin. 2000. Soil organic matter formation and sequestration across a forested floodplain chronosequence. Ecological Engineering 15:S141-155.

Wike, L. D., F. D. Martin, H. G. Hanlin, and L. S. Paddock. 2000. Small mammal populations in a restored stream corridor. Ecological Engineering 15:S121-129.

Winne, C. T., and T. J. Ryan. 2001. Aspects of sex-specific differences in the expression of an alternative life cycle in the salamander *Ambystoma talpoideum*. Copeia 1:143-149.

Winne, C. T., T. J. Ryan, Y. Leiden, and M. E. Dorcas. 2001. Evaporative water loss in two natricine snakes, *Nerodia fasciata* and *Seminatrix pygaea*. Journal of Herpetology 35:129-133.

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 FY '01 are listed in Table 1.

The SREL Education Program has averaged 20 undergraduate students per year since 1968. These students, from over 100 different colleges and universities, have been co-authors on 120+ peer reviewed research publications; more than 100 of these students have gone on to pursue careers in science. The Undergraduate-Research Experience for Undergraduates, funded by the National Science Foundation, is in its third year and this year we sponsored 12 students. In addition, we sponsored two students from HBCUs, mentored one student funded through Westinghouse SRC, and one student funded by SREL and USC Honor College, Columbia.

Since 1967, an average of six students a year has completed graduate studies at SREL and over 272 dissertations and theses have been written. During FY'01 five students completed their degree requirements (two M.S. and three Ph.D.). Since 1985, our graduate students have won over 156 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.

SREL Graduate Students Completing Degree Requirements

Jeffrey French, Ph.D. student - University of South Carolina - Travis Glenn
Evan Perry, M.S. student - University of Georgia - Chris Romanek
Gordon Plague, Ph.D. student - University of Georgia- J Vaun McArthur
Brandon Staub, M.S. student - University of Georgia - Justin Congdon
Mark Wise, Ph.D. student - University of Georgia - J Vaun McArthur

TABLE 1. SREL Undergraduate and Graduate Student Program Participants

Undergraduate Research Participation Program

Student	Academic Institution	Faculty Advisor
Heather Bartley	University of South Carolina, Columbia	Lee Newman
Jessica Brown	Maryville College, TN	Lee Newman
Laura Bukovitz	University of Tennessee, Knoxville	Kenneth McLeod
Christopher Carter	Anderson College, SC	I. Lehr Brisbin
Jaclin DuRant	University of South Carolina, Columbia	Lee Newman
Ovuekoghene Irune	Clark Atlanta University, GA	John Seaman
Elizabeth Jackson	Clark Atlanta University, GA	John Seaman
Natalia Johnson	Claflin University, SC	Tom Hinton
Liberty Moore	University of Georgia, Athens	Travis Glenn/I Lehr Brisbin
Christopher O'Neil	Georgia Southern University, Statesboro	I. Lehr Brisbin
Kirkwood Russell	Clark Atlanta University, GA	John Seaman
Ryan Stokes	Ohio State University, Columbus	J Vaun McArthur
Denise Strickland	University of South Carolina, Columbia	Travis Glenn
Pamela Weisenhorn	Louisiana State University, Baton Rouge	Beverly Collins
Annette White	Pensacola Christian College, FL	J. Whitfield Gibbons

Graduate Research Participation Program

Student	Degree	Institution	Faculty Advisor
Gian Paolo Aspette	Ph.D.	Universita Cattolica S. Cuore, Italy	Domy Adriano
Jennifer Brofft	Ph.D.	University of Georgia, Athens	J Vaun McArthur
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
Michael Collyer	Ph.D.	North Dakota State University, Fargo	Michael Smith
Lisa Davis	M.S.	University of South Carolina, Columbia	Travis Glenn
Daniel Dawson	M.S.	Colorado School of Mines, Golden	John Seaman
Susan Dietz	M.S.	University of Georgia, Athens	Barbara Taylor
Jeffrey French	Ph.D.	University of South Carolina, Columbia	Travis Glenn
Wouter Geebelen	Ph.D.	Limburgs Universitiar Centrum, Belgium	Domy Adriano
Susanne Hauswaldt	Ph.D.	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
Mark Komoroski	Ph.D.	University of Georgia, Athens	Justin Congdon
Yong Jin Lee	Ph.D.	University of Georgia, Athens	Christopher.Romanek
Andrea Lowrance	M.S.	University of Georgia, Athens	Rebecca Sharitz
Julie Murray-Weston	Ph.D.	University of Georgia, Athens	I. Lehr Brisbin
Taras Oleskyk	Ph.D.	University of Georgia, Athens	Michael Smith
Evan Perry	M.S.	University of Georgia, Athens	Christopher.Romanek
Gordon Plague	Ph.D.	University of Georgia, Athens	J Vaun McArthur
Jeffrey Retzke	M.S.	Medical University of South Carolina, Charleston	Paul Bertsch
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
Brandon Staub	M.S.	University of Georgia, Athens	Justin Congdon
Robert Thomas	Ph.D.	University of Georgia, Athens	Christopher Romanek
Ria Tsaliagos	M.S.	University of Georgia, Athens	J. Whitfield Gibbons
Olga Tsyusko	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 Unterkoefler	Ph.D.	Austria	Domy Adriano
Chelsea Ward	Ph.D.	Auburn University, AL	Thomas Hinton
Mark Wise	Ph.D.	University of Georgia, Athens	J Vaun McArthur

SPECIAL, ACCOMPLISHMENTS OF FACULTY, STAFF, STUDENTS, AND ADMINISTRATION

Honors and Awards

Dr. Justin Congdon was awarded the 2000 Longevity Prize by the Foundation IPSEN, a French organization that supports work in the field of longevity. Since 1997 the annual prize has gone to researchers in such fields as biology, genetics, gerontology, demography and statistics; Congdon is the first ecologist to win the award. Congdon will receive 100,000 French francs and deliver a lecture based on his work with longevity in Blanding's turtles in July 2001 at the World Congress of Gerontology in Vancouver Canada.

Dr. Domy Adriano's second edition of his book "Trace Elements in Terrestrial Environments-Biogeochemistry, Bioavailability, and Risks of Metals," was published in late June 2001.

Ms. Virginia Jin was approved for funding for an NSF Doctoral Dissertation Improvement Grant. She's a student with Becky Sharitz studying plant organic nitrogen uptake in temperate ecosystems and how this may affect ecosystem nutrient cycling. Her $7,200 grant is for two years and places her in the top one-quarter of grant applicants.

Dr. Paul Bertsch, SREL Director, was invited to participate in a workshop sponsored by a National Academy of Sciences committee on "Building a Long-Term Environmental Quality Research and Development Program in the U.S. Department of Energy." The workshop was held in August 2000 in Washington, D.C. and focused on the most significant issues and needs to be considered for DOE's long-term environmental quality research and development efforts. The workshop included participants from a variety of organizations, including DOE, the National Science Foundation, U.S. Environmental Protection Agency, DOE National Labs, the President's science advisory staff, private industry, and academia.

Olga Tsyusko received a small grant from Sigma Xi in support of her research project entitled "Radiation Induced Mutations in Cattails from Chernobyl." Ms. Tsyusko, a graduate student in Interdisciplinary Toxicology at UGA, is studying the influence of long-term radiation on populations of aquatic plant, cattail, in the Chernobyl exclusion zone, Ukraine.

The **SREL Education Program** was honored in February 2001 with the first "UGA Excellence in Undergraduate Research Mentoring Award" from the Center for Undergraduate Research Opportunities and the Office of the Senior Vice President for Academic Affairs and Provost.

Dr. Whit Gibbons, founding member of Partners in Amphibian and Reptile Conservation (PARC), received an Environmental Merit Award from the U.S. Environmental Protection Agency Region 4 during an awards ceremony at the Jimmy Carter Presidential Center in Atlanta in October 2000. He accepted for PARC, which took the award for Environmental, Community and Non profit organizations. The Environmental Merit Awards program provides the EPA an opportunity to reach out to individuals, states, federal partners, local governments, stakeholder groups, businesses, and others who made specific contributions in 1999-2000 to improve the environment. The EPA named 47 winners from more than 250 nominations in EPA Region 4.

Dr. Paul Bertsch was appointed by Dr. Karen Holbrook to the Implementation Committee for the New UGA College of the Environment.

Lisa Davis received first place in the Graduate Student Day competition, Biological Sciences Division, at the University of South Carolina for her oral presentation. Lisa is a graduate student working with Travis Glenn.

Dr. John Seaman has been promoted to Associate Research Scientist.

Dr. Whit Gibbons was recognized at The University of Georgia's annual Institute of Ecology awards banquet, where he received the Outstanding Ecology Instructor Award.

Bill Hopkins along with **Chris Rowe** recently were awarded $280,059 (2 years) from the U.S. EPA-Star grant program in the Wildlife Risk Assessment Area. Their proposal was entitled "Modeling the individual and interactive risk to an amphibian population resulting from breeding site contamination and terrestrial habitat loss." The work will be conducted on the SRS.

Dr. Paul Bertsch was invited by the Carlsbad Environmental Monitoring and Research Center in Carlsbad, NM, to participate in their Scientific Advisory Board Review Committee.

Drs. Domy Adriano and **Mike Smith** attended the 4th Annual Conference of the International Chornobyl Center in Slavutych, Ukraine in October 2000. This conference focused on the scientific, technical and social aspects of the Chornobyl Nuclear Power Plant accident and closure.

SREL was selected as one of only seven universities nationwide to participate in an exhibition at "The Science Coalition" program *University-based research–investing in the future*, in Washington D.C in July 2000. SREL, represented by **Drs. Paul Bertsch** and **Carl Strojan** and **Jeff Harris**, presented a poster and computer-based presentation on "Synchrotron X-ray Sources and New Opportunities in the Environmental Sciences."

Dr. Paul Bertsch was invited by the Carlsbad Environmental Monitoring and Research Center in Carlsbad, NM, to participate in their Scientific Advisory Board Review Committee. **Dr. John Seaman** was invited to serve on the Scientific Proposal Review Panel for the U.S. Army Corps of Engineers Project BT25–Environmental Quality Basic Research.

Chris Winne won the Marilyn M. Odom Outstanding Graduate Student Award for outstanding graduate student of 2000-2001 awarded by Stephen F. Austin State University School of Graduate Studies and the SFASU Alumni Foundation. His 4.0 average and his 1,010 score on the GRE helped earn him this honor. He is a student of Whit Gibbons.

Dr. Paul Bertsch received funding from the Environmental Protection Agency for a new research project, "Effects of Natural and Anthropogenic Compounds and Suspended Colloids on Partition Coefficients for Selected Radionuclides and Other Inorganic Contaminants." This was an interagency agreement between DOE and EPA and is for $100,000.

Larry Bryan, **Bobby Kennamer**, **Karen Gaines** and **Dr. I. Lehr Brisbin** received a $75 K grant from the Augusta Airport to continue their studies on birds in the vicinity of the airport and the potential threat to aircraft.

Dr. Justin Congdon was awarded $52,800 for Life History and Demography of Turtles and Tortoises from USGS.

The Encyclopedia Britannica's 2001 Britannica

Book of the Year section on Life Sciences includes research done at SREL that shows a global decline of reptiles as among the most significant research published last year. **Dr. Whit Gibbons**, an ecologist with the University of Georgia, published an article in BioScience last year that detailed the decline of many species of reptiles.

Ms. Virginia Jin received the first annual Undergraduate Research Mentorship Award from UGA. This Award was presented at the closing ceremony of CURO, the undergraduate research symposium sponsored by the UGA Honors Program.

Michelle Lakly was named as Zoo Atlanta's new Director of Education. Ms. Lakly completed her Master 's degree at SREL under the direction of Dr. J Vaun McArthur. In her new position Lakly will keep her scientific ties and continue with her research efforts. She may also travel annually with other zoo personnel to Kenya, China or the Galapagos, where Zoo Atlanta has ongoing research sites.

Dr. J Vaun McArthur was one of a small group of UGA faculty selected to participate in an NIH funding forum.

Dr. Paul Bertsch served on a team that evaluated the School of Natural Resources at Ohio State University.

Dr. Whit Gibbons received first place in color photography from the South Carolina Outdoor Press Association for his photo of a copperhead snake. The winning photo ran with an article he wrote on the same topic that appeared in a hunter's magazine Quality Whitetails.

Dr. Christopher Romanek has been promoted to Associate Professor of Geology and Associate Research Scientist. Dr. Romanek is known for his work on the life on mars project.

Warren Safter has been awarded a Distinguished Service to Safety Award by the Campus Safety Division of the National Safety Council. This award, which recognizes outstanding service of the Council's Campus Safety Division, the employer, and other organizations, is given to only a handful of individuals annually.

Dr. John Seaman was invited to serve on the Scientific Proposal Review Panel for the U.S. Army Corps of Engineers Project BT25–Environmental Quality Basic Research.

In September 2000, **Drs. Paul Bertsch, Ron Chesser** and **Carl Strojan** attended meetings with Dr. Carolyn Huntoon and a delegation from the University of South Carolina at the International Radioecology Laboratory in Ukraine. Dr. Huntoon, then Assistant Secretary for Environmental Management at the Department of Energy in Washington, D.C., provided centralized management for DOE's environmental restoration programs.

Dr. Whit Gibbons served on a National Research Council (National Academy of Sciences) committee on Mitigating Wetland Losses.

Externally Funded Grants

PI: Domy C. Adriano
Project Title: Surface Water Chemistry and Revegetation of 488-D Ash Basin
Funding Agency: USDA Forest Service
Funding Level: $16,000

PI: Paul M. Bertsch
Project Title: The Environmental Fate of Arsenic from Poultry Litter
Funding Agency: U. S. Department of Agriculture
Funding Level: $164,000

PI: Paul M. Bertsch
Project Title: Characterization of C_s Binding to INEEL Soils
Funding Agency: Bechtel BWXT Idaho
Funding Level: $114,000

PI: I. Lehr Brisbin
Project Title: Studies on Clapper Rails in Coastal Marshes
Funding Agency: Savannah Presbytery M.K. Pentecost Ecology Fund
Funding Level: $6,000

PI: I. Lehr Brisbin
Project Title: Aerial Surveys of water birds in the vicinity of Bush Field Airport and the Augusta Wastewater Treatment Plant
Funding Agency: Augusta-Richmond County
Funding Level: $75,748

PI: I. Lehr Brisbin
Project Title: Contaminants and Risk at the Savannah River Site
Funding Agency: Rutgers, The State University
Funding Level: $32,880

PI: I. Lehr Brisbin
Project Title: Monitoring Coastal Wood Stork Colonies in 2000: Breeding Success and Mercury Concentrations
Funding Agency: U.S. Department of Interiors
Funding Level: $17,515

PI: I .Lehr Brisbin
Project Title: A Study to Evaluate Bird-Strike Hazards to Aircraft Operations at the Aiken Airport

Funding Agency: Southeastern Environmental Solutions, Inc.
Funding Level: $21,518

PI: I. Lehr Brisbin
Project Title: A Proposal to Produce an Educational Brochure Concerning Wood Stork Ecology, Behavior, and Conservation
Funding Agency: U.S. Department of Interior
Funding Level: $19,810

PI: Justin D. Congdon
Project Title: Life History and Demography of Desert Tortoises
Funding Agency: U.S. Geological Survey
Funding Level: $52,800

PI: J. Whitfield Gibbons
Project Title: Sublethal Effects of Pesticide Exposure
Funding Agency: U.S. Golf Association
Funding Level: $28,700

PI: J. Whitfield Gibbons
Project Title: Webster's Salamander Inventory and Monitoring
Funding Agency: U.S. Department of Agriculture
Funding Level: 8,000

PI: J. Whitfield Gibbons
Project Title: Amphibian and Reptile Inventory & Monitoring
Funding Agency: U.S. Department of Agriculture
Funding Level: $14,000

PI: J. Whitfield Gibbons
Project Title: Development, Production, and Distribution of Environmental Education Materials for Indigo Snake Protection and Hognose Snake Research
Funding Agency: U.S. Department of Interior
Funding Level: $68,400

PI: J. Whitfield Gibbons
Project Title: R & D of Conservation Plans for Establishment of a Population of Gopher Tortoises on Aiken Preserve
Funding Agency: SC Department of Natural Resources
Funding Level: $9,992

PI: J. Whitfield Gibbons

Project Title: Inventory and Monitoring of Reptiles and Amphibians
Funding Agency: Department of Interior, National Park Service
Funding Level: $158,035

PI: J.Whitfield Gibbons
Project Title: Development and Maintenance of PARC Website
Funding Agency: U.S. Dept. of Commerce/NOAA
Funding Level: $2,500

PI: J.Whitfield Gibbons
Project Title: Development of Habitat Guidelines for Herpetofauna
Funding Agency: U.S. Forest Service
Funding Level: $60,000

P.I.: J. Whitfield Gibbons
Project Title: Enhancing Amphibian and Reptile Biodiversity on Golf Courses through Use of Seasonal Wetlands, Amendment No.2
Funding Agency: U.S. Golf Association
Funding Level: $23,461

PI: Thomas G. Hinton
Project Title: Stabilizing Cesium-Contaminated Sediments through the Addition of Illite Clays
Funding Agency: Education, Research, and Development Association
Funding Level: $25,812

P.I.: J Vaun McArthur
Project Title: REU: The Impact of Energy Technologies on Natural Environments
Funding Agency: National Science Foundation
Funding Level: $14,000

P.I.: J Vaun McArthur
Project Title: Movement of Contaminated Fish Between SRS Streams and the Savannah River
Funding Agency: Education Research and Development Association
Funding Level: $82,774

PI: Kenneth W. McLeod
Project Title: Assessment of Harvesting Bottomland Hardwood Sites on Plant Composition and Ecosystem Processes
Funding Agency: USDA Forest Service
Funding Level: $28,668

PI: Christopher S. Romanek
Project Title: Controlled Growth of Biologic and Abiotic Carbonates and Fe-oxides
Funding Agency: NASA Johnson Space Center
Funding Level: $10,000

PI: Christopher S. Romanek
Project Title: Savannah River Ecology Laboratory's "Don't Duck Metadata"
Funding Agency: U.S. Department of the Interior
Funding Level: $3,080

PI: John C. Seaman
Project Title: Tritium Distribution, Mixing, and Transport at the Tritiated Water Management Facility Southwest Plum Interim Measures
Funding Agency: (USDA) USFS-SR
Funding Level: $38,905

PI: Rebecca R. Sharitz
Project Title: Creation of a Geographic Information Systems Program Plan for the Congaree Swamp National Monument and a GIS Metadata Program for the National Parks in the Southeast Coastal Network
Funding Agency: U.S. Department of Interior
Funding Level: $61,213

PI: Rebecca R. Sharitz
Project Title: Vegetation Monitoring of Restored Depression-Wetlands on the Savannah River Site, South Carolina
Funding Agency: USDA Forest Service, Savannah River Institute
Funding Level: $17,000

PI: Barbara E. Taylor
Project Title: Characterization of invertebrate assemblages in Carolina bays and other wetland ponds before and after restoration treatments
Funding Agency: U.S. Department of Agriculture
Funding Level: $5,000

PUBLICATIONS

Books Published and in Press

Adriano, Domy C. 2nd edition. Trace Elements in Terrestrial Environments: *Biogeochemistry, Bioavailability, and Risks of Metals.* Springer-Verlag, New York. p. 1-866.

Journal Articles and Book Chapters Published

2448 Peles, J. D., T. Philippi, M. H. Smith, I. L. Brisbin, Jr., and J.W. Gibbons. 2000. Seasonal variation in radiocesium levels of largemouth bass (*Micropterus salmoides*): Implications for humans and sensitive wildlife species. Environmental Toxicology and Chemistry 19:1830-1836.

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2453 Ulsh, B. A., M. C. Mühlmann-Díaz, F. W. Whicker, T. G. Hinton, J. D. Congdon, and J. S. Bedford. 2000. Chromosome translocations in turtles: a biomarker in a sentinel animal for ecological dosimetry. Radiation Research 153:752-759.

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Planorbidae) from Kenya. Zoological Journal of the Linnean Society 129:387-401.

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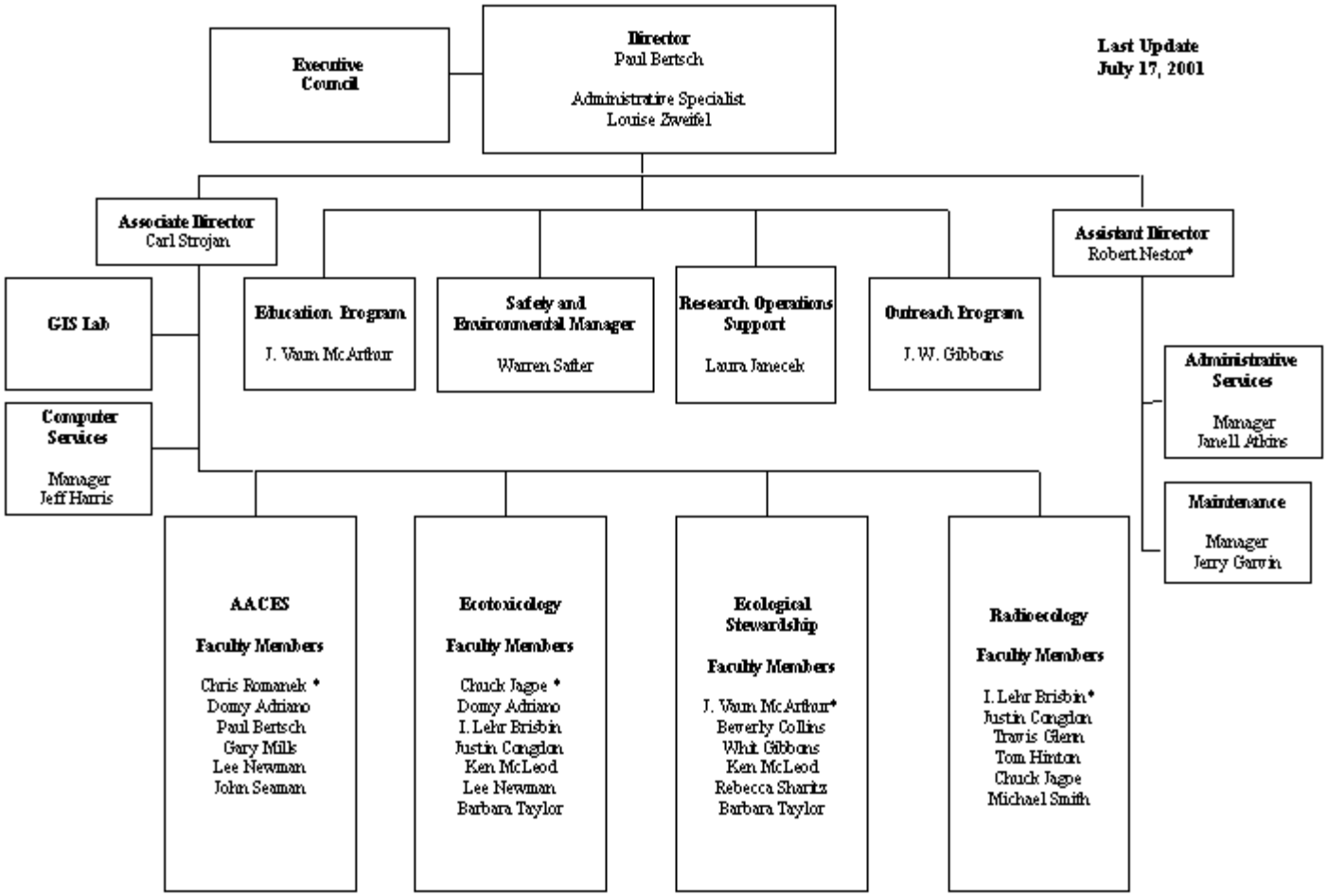
APPENDIX. Figure 1. Organization Chart, Savannah River Ecology Laboratory



* Denotes Group Representative to Executive Council