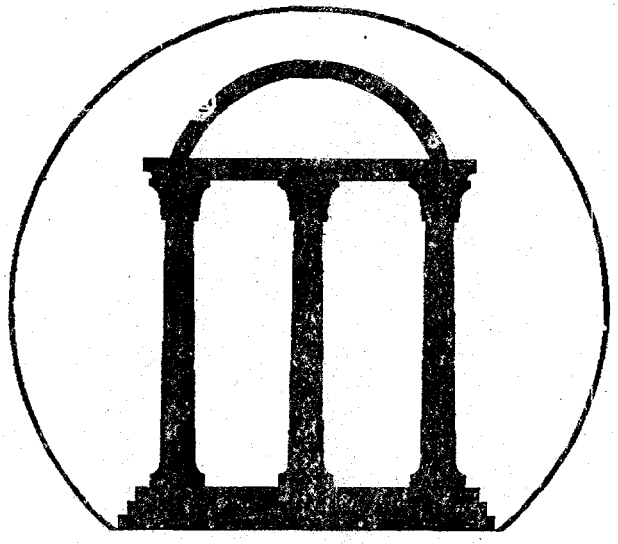
SRO--819-28

SAVANNAH RIVER ECOLOGY LABORATORY

ANNUAL TECHNICAL PROGRESS REPORT



University of Georgia - Savannah River Ecology Laboratory

1997

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SRO--819-28

SAVANNAH RIVER ECOLOGY LABORATORY

ANNUAL TECHNICAL PROGRESS REPORT

OF

ECOLOGICAL RESEARCH

SUPPORTED UNDER COOPERATIVE AGREEMENT

DE-F609-96SR18546

BETWEEN THE UNIVERSITY OF GEORGIA

AND THE U.S. DEPARTMENT OF ENERGY

FOR THE YEAR ENDING

JUNE 30, 1997

Michael H. Smith, Director

Prepared by Gary Wein and Brenda Rosier

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SUMMARY

The Savannah River Ecology Laboratory (SREL) is a research unit of the University of Georgia (UGA). 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) at the Savannah River Site (SRS) near Aiken, South Carolina. Significant accomplishments were made during the past year in the areas of research, education, and service.

The Laboratory's research mission was fulfilled with the publication of three books and 94 journal articles and book chapters by faculty, technical staff, students, and visiting scientists. An additional four books and 125 journal articles have been submitted or are in press. Researchers archived 197 data sets into the SREL Data Archive System. Several other noteworthy events took place as faculty members received awards and conducted conferences. Dr. Justin D. Congdon organized and conducted the Fourth Annual SREL Symposium on the Environment titled "Resource Allocation Processes: The Connection Between Individual and Population Levels of Biological Organization" in January 1997. Drs. Michael C. Newman and Carl L. Strojan organized and conducted a workshop titled "Risk Assessment: Logic and Measurement" that was held at the SREL Conference Center in August 1996. Dr. Newman also developed and taught a course on Quantitative Methods in Ecotoxicology at the SREL Conference Center in July 1996. Dr. Domy C. Adriano, along with faculty from the University of California and the U.S. Army Cold Regions Research and Engineering Laboratory, cosponsored the Fourth International Conference on the "Biogeochemistry of Trace Elements" at the University of California during June 1997.

Notable scientific accomplishments include work conducted on diatoms, frog tadpoles, and the further development of the Laboratory's analytical capabilities. Research by Dr. Barbara E. Taylor and graduate student Evelyn Gaiser explored the development of the fossil-poor modern coastal plain biota and landscape by examining siliceous diatoms in a depressional wetland on the SRS. Their evidence indicates that the Savannah River laterally migrated to its current location 4000-5000 ybp. Research by Dr. Justin D. Congdon in the SRS coal fly-ash basins has revealed that morphological development of some aquatic organisms, such as frog tadpoles, may be affected by the various heavy metals characteristic of these areas. This research is being expanded to examine physiological and genetic effects on a number of other aquatic and terrestrial organisms. During the past year SREL purchased and installed a $539,000 Fourier Transform Mass Spectrometer using matching funds from DOE and UGA Lottery Funds. This will raise SREL's analytical capabilities to a new level of sophistication, allowing researchers to analyze organic chemicals such as those found in mixed wastes from contaminated sites. A three-year Education, Research and Development Association of Georgia Universities (ERDA) contract to establish an Advanced Analytical Center for Environmental Sciences (AACES) was completed in June of this year.

Certainly one of the more exciting and high profile research events of the year was the

announcement of the possibility of life on Mars. This was based on a paper coauthored by researcher Dr. Christopher S. Romanek and published in *Science* (McKay, D. S., E. K. Gibson Jr., K. L. Thomas-Kerpta, H. Vali, C. S. Romanek, S. J. Clement, X. D. F. Chillier, C. R. Maechling, and R. N. Zare. 1996. Search for past life on Mars: Possible relic biogenic activity in Martian meteorite ALH84001. *Science* 273:924-930). This paper presented evidence consistent with microfossil remains of past Martian biota and was the result of research conducted by a team at the Johnson Space Center.

The Savannah River Ecology Laboratory played a pivotal role in the development of the Environmental Centers of Excellence Program at the Savannah River Site. These centers include the National Water Research Center, the Soil Remediation Research Center, and the International Initiative in Radioecology. Membership in these centers includes SREL and the ERDA and South Carolina Universities Research and Education Foundation (SCUREF) Universities. As a result of this effort, the DOE-Savannah River Site's Office of Science, Technology and Business Development requested proposals; SREL faculty submitted 19 proposals, of which seven were funded. Awards over three years total $3,010,351.

Participants in the SREL Education Program during 1996 and 1997 came from schools located throughout the United States and included 24 undergraduate students, 50 graduate students, and two visiting faculty. These participants come from more than 20 states, emphasizing the national stature of the SREL program In the past year one graduate student from the SREL earned Masters Degrees and four earned Doctor of Philosophy Degrees. SREL was awarded 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," in April 1996. This award is being used to support undergraduate education in the summers of 1996 and 1997.

In addition to holding faculty positions at the University of Georgia, various SREL faculty have adjunct status at 30 other colleges and universities. Faculty, staff and students also are active in providing outreach and service to the scientific community. Representatives from SREL hold more than 40 editorial or committee positions in national groups and organizations and also serve on several UGA academic and administrative committees. Over 170 lectures, scientific presentations, and posters were presented during the past year at colleges and universities, including minority institutions.

The SREL Outreach Program reaches a different audience in its successful efforts to communicate scientific awareness to the general public. In 1996, Outreach staff gave 311 lectures, 47 tours, 23 exhibits, and 31 workshops to schools, civic groups, and similar audiences, reaching more than 100,000 people. This year they published a brochure titled "The National Environmental Research Park at Savannah River Site" in celebration of the 25th anniversary of the SR-NERP.

The Southeastern Outdoor Press Association (SEOPA) has awarded the SREL Outreach Program a second place "Excellence in Craft" award in the "Best in Public Relations/Supporting Member" category in honor of the Program's publication titled "Biodiversity, Prospect & Promise

for the Savannah River Site, A National Environmental Research Park." The publication competed with entries from many sporting and outdoor equipment companies from across the nation. Also, the SEOPA awarded a second place "Excellence in Craft" award for radio commentary, to Dr. J. Whitfield Gibbons. This award honors his "Ecoview" commentaries on National Public Radio (NPR) affiliate station WUGA-FM in Athens, Georgia. Dr. Gibbons' commentaries also have been aired on the NPR program "Living on Earth."

Major additions to the SREL facilities were completed that will enhance the Laboratory's work in the future. The construction of a 5,000 ft^2 laboratory addition has been finished. It will house three multiuser laboratories designed to facilitate research initiatives in molecular ecology, environmental chemistry and bioremediation, and will triple the space available for analytical equipment. A new 5,000 ft^2 Animal Care Facility has been constructed and was occupied in January 1997. Phones and computer network capabilities were added to the new technical office building, allowing telecommunications with this space. A 3,500 ft^2 building with four classrooms for distance learning has been set up and the hardware for two classrooms is operational. Furniture for a third traditional classroom also has been purchased. The Conference Center has continued to see wide use, both by SREL and the local community. The facility was used to host a total of 166 scientific meetings and environmental education programs for students, teachers and the general public this past year. Initial plans for a greenhouse renovation and Plant and Soil Processing Facility are being developed. This project's $1 million FY '97 construction budget has been postponed until FY '98 by DOE funding delays.

Representatives of the Laboratory also serve local and statewide communities by organizing blood drives, managing a recycling program, participating generously in the UGA Campaign for Charities, and hosting an annual auction benefitting the South Carolina Chapter of The Nature Conservancy.

Several steps were taken to improve the overall management and operation of the SREL. An internal performance review was completed for the Laboratory Director. In follow-up, the review was extended to include the three members of the Office of the Director. Several recommendations were made to the Director for implementation. During April 1997, a review of the SREL Scientific Programs was conducted by DOE. Results of this review are anticipated this summer. Many of the recommendations suggested by an FY '96 Reorganization Committee were initiated on July 1, 1997. The resulting reorganization of the Laboratory structure will create four research programs with elected representatives to an Executive Council which will allow the SREL to respond to the changing mission of the Department of Energy and the Savannah River Site.

OVERVIEW OF RESEARCH PROGRAMS AND PROGRAM COMPONENTS

During FY '97 SREL reorganized its programs and established four new research groups of investigation building both on past experience of the former Divisions of Biogeochemical Ecology, Wetlands Ecology, and Wildlife Ecology and Toxicology and on current DOE-SR research needs. Within each of the four groups new programs are being developed to be initiated in FY '99. Because expediency is needed to meet rapidly changing DOE needs, SREL researchers are beginning to initiate these new programs in FY '98. However, because FY '98 is a transition year and the purpose of this document is to report research activities during FY '97; we are presenting the old programs under the new research program structure. Below are program descriptions of the four new research groups that are being initiated in FY '98 and to be fully implemented in FY '99.

A. 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*
- *Environmental computational chemistry.*

AACES objectives are to:

- *Serve as an advanced research facility with a primary interest in bridging basic and applied environmental research from the molecular level to ecosystems*
- *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.*

Amount and Chemical Forms of Uranium Transported from the Tims Branch/Steed Pond System to Upper Three Runs Creek

Paul M. Bertsch

Uranium is a widespread contaminant introduced into the environment as a result of mining and manufacturing activities related to the nuclear power industry, detonation of U-containing munitions at Department of Defense facilities, and as a result of nuclear weapons materials production and processing at Department of Energy (DOE) facilities. At DOE facilities, U is the most common radionuclide contaminant in groundwater/sediment systems and is often found associated with other metals such as Ni, Cr, and Cu. One example of such an environment is the Tims Branch stream which flows adjacent to M-Area. As a result of fuel fabrication operations in M-Area, large amounts of U (~43,545 kg), Ni, and chlorinated hydrocarbons were released into Tims Branch, a second-order stream which drains an area of approximately 16 km^2 within the drainage basin of the Savannah River. Tims Branch flows directly into Upper Three Runs Creek (UTRC), which in turn flows into the Savannah River. It is estimated that more than 97% of all gross alpha activity released to the environment from SRS facilities was as U discharged from M-Area operations. Furthermore, it is estimated that most of the U remains in depositional environments of the Tims Branch system, with ~ 30,721 kg, or ~70% of the total residing in the exposed sediments of the area formerly submerged by Steed Pond, which drained upon failure of the spillway in 1984. These sediments have U concentrations as high as 6,000 mg/kg, which are often associated with equal concentrations of Ni, a co-contaminant in this system and among the most common metal contaminants at National Priority List (NPL) sites nationwide. Thus, some sediments surrounding the area formerly submerged by Steed Pond are among the most heavily contaminated sediments on the SRS.

Transport studies consisted of installing automated sampling devices at two locations in Tims Branch to collect stream samples during storm events. These locations were chosen to provide estimates of the U concentration transported from Steed Pond into UTRC, and because they are locations of United States Geological Survey flow monitoring stations. Site 1 is approximately 129 m downstream of Steed Pond dam. Site 2 is approximately 182 m upstream of the Tims Branch-UTRC confluence. Water samples from Tims Branch were collected at timed intervals of 1-2 hours along the hydrograph during rain events. A rain gauge was installed at site 1 and checked periodically to monitor the storm intensity. Hourly samples were collected until the rate of change in flow decreased significantly as determined from the hydrograph; the stream was then sampled at two hour intervals until base flow was achieved.

An aliquot of the hourly stream samples was digested using a $HF/HCL/HNO_3$ digestion method in Teflon pressurized bombs with microwave heating. Digested samples were then transferred to acid-washed polyethylene bottles. Another aliquot of the hourly samples was filtered through a 0.45 μm polycarbonate filter and acidified to 1% v/v with ultra pure concentrated nitric acid. Total U was measured in both filtered and unfiltered samples by inductively coupled plasma mass spectrometry (ICP MS). Field blanks using distilled water were prepared every 20 samples at

each site in the same manner as the stream samples to identify sources of possible contamination. Base flow samples were collected prior to storm events to establish background U levels. Additional water samples were collected along the storm hydrograph (ascending limb, peak, descending limb) at Site 1 by an automatic sampler.

Four storms were monitored during the course of this study. The storms varied in intensity and duration, resulting in a range of rainfall conditions for comparison. It was determined that rain intensity in the Tims Branch watershed must exceed 12.7 mm in a 24 hour period for a detectable increase in runoff and sediment load to be distinguished. All storms observed exceeded this limit. Fifteen years of historical rainfall data for SRS showed that rainfall will exceed this limit an average of 29 times per year, and rainfall typical of the storms monitored in this study will occur an average of 13 times per year. Remobilization of sediment-associated U from contaminated floodplain sediments of Steed Pond during these episodic rain events was investigated. Total U transported during all four storms followed Tims Branch discharge patterns. This would suggest that more U is transported on a mass basis during episodic rain events than during base flow. The mass flux of U transported during base flow was calculated based on the same duration as the storm. The base flow calculations were based on an average discharge of 127.4 L/S and an average daily U concentration of 4.2 μg/L. Uranium contribution from base flow was subtracted from the storm contribution by component separation of the storm hydrograph. Using historical data and rainfall measured during this study, U mass flux calculations show the amount of U transported from Steed Pond during one storm day equals approximately 43 to 65 base flow days. During the various storm events measured, approximately 1500 to 2800% more U was exported to Upper Three Runs Creek (UTRC) relative to base flow measurements and a typical storm. Mass flux estimates determined from base flow measurements potentially underestimate the amount of U transported from contaminated terrestrial sources to surface water systems. Erosional processes can effectively mobilize sediment-associated contaminants during storms or flooding. Additional studies are needed to quantify U mass flux on a yearly basis; however, considerable more U is transported to UTRC than base flow calculations indicate. This demonstrates the need to assess contaminant remobilization during the entire storm event to avoid missing peak contaminant concentrations during peak flow rates.

Uranium solid phase associations in suspended sediments were assessed by a sequential chemical extraction procedure to gauge U chemical lability. Sequential extraction results suggest the suspended sediment load transports the bulk of U in labile forms predominantly as acid soluble (specifically adsorbed), MnO_2 occluded and organically bound phases. Only a small percentage of U was contained in the residual phase. The descending and base flow sequential extraction results show the same association trend as the ascending and peak sediments. The results indicate that more Mn and organically-bound phases are mobile during periods of higher discharge, while a greater amount of U is associated with acid soluble (specifically adsorbed) phases during base flow and during low discharge. This trend is consistent with the removal of organic material, and the associated U, from the contaminated sediments during a storm. During base flow, it is expected that the smaller clay and colloidal size particles are mobile and would transport most of the U. The efficiency of the extraction procedure was assessed by comparing the sum of the fractions to the total U in each unknown and control sample. The results indicate that a high percentage of the U was

recovered during the extraction procedure (92-99% recovery). These data suggest that U mobilized in the Tims Branch system is associated with the more chemically labile phases. This implies that U may be available to the ecosystem under a range of geochemical conditions likely to be encountered within depositional environments (e.g., Eh and pH) or as a result of industrial processes.

Transformation Reactions of SRS-relevant Organics: 1. Characterization Of Biodegradation Rates Of Separated Diesel Components

Gary L. Mills and Jennifer J. Olson

In situ bioremediation has been applied successfully to hydrocarbon contaminated sites and interest *in situ* bioremediation as a cost-effective alternative to traditional remediation techniques continues to grow. The EPA estimates that 30% of petroleum contaminated sites in the United States currently use bioremediation as part of their restoration efforts. One obstacle to expanded use of bioremediation is lack of accurate predictive models. Development of predictive models requires data that address both intrinsic rates of hydrocarbon biodegradation and dependency of these rates on petroleum composition. The focus of this research is to determine intrinsic rates of biodegradation of major classes of diesel fuel hydrocarbons as separated components, and to compare these rates to those observed in a composite mixture.

Initial studies of hydrocarbon biodegradation based on simple mixtures suggested that hydrocarbons are degraded in the following sequence: n-alkanes > cyclic alkanes > aromatics. However, other studies with complex mixtures such as whole fuels have shown that hydrocarbons in petroleum fuels do not follow a simple degradation sequence and that the relative rates of specific compounds vary among different fuels. These studies indicate that interactions between hydrocarbons of different classes influence rates of biodegradation of specific compounds, and of entire hydrocarbon classes. Without data on rates of biodegradation of the compounds and classes that are independent from the complex mixture, it is difficult to extrapolate data to use as a predictive tool for other fuels or as fuel-composition changes due to weathering. The biodegradation rates of specific compound classes isolated from complex mixtures versus composite hydrocarbon mixtures have not been reported. Our research may provide data that would be better suited for predicting the effect of petroleum composition on the rates of microbial degradation in both natural and accelerated remediation applications.

The objectives of this study were (1) to quantify the rates of biodegradation of three hydrocarbon classes: n-alkanes, branched and cyclic alkanes, and aromatics, both when present individually as the sole carbon source and when present as a composite mixture in microcosm experiments; and (2) to determine how the rates of biodegradation for the whole compound classes and specific compounds within each class were influenced by the hydrocarbon assemblage. Hydrocarbon classes were isolated from the diesel fuel mixture using silica chromatography. Recovery of n-alkanes from the 5A molecular sieve zeolites requires the use of aggressive chemical treatments (e.g., hydrochloric acid) that might damage the integrity of the hydrocarbons,

consequently, a n-alkane solution that mimicked the distribution of n-alkanes in the original diesel was prepared from standards. Portions of each of the three hydrocarbon classes were recombined to prepare a composite solution that resembled the original diesel. Each microcosm contained 4 mg hydrocarbons per 1 ml of culturing media and was inoculated with a microbial consortium isolated from a creosote contaminated site enriched on diesel fuel. After inoculation, microcosms were incubated at 30^0 C while shaking at 200 RPM to optimize microbial growth. Three microcosms were destructively sampled for heterotrophic bacterial plate counts and hydrocarbon composition on days 0, 3, 7, 15, and 35. Hydrocarbon extracts were quantified with gas chromatography-flame ionization detection (GC-FID) and specific compound identification was confirmed with gas chromatography-mass spectrometry (GC-MS) analysis.

Samples extracted from the microcosms containing the composite solution were fractionated on silica gel solid phase extraction columns prior to GC-FID and GC-MS analysis. The aliphatic fractions of the composite samples contain the – alkanes and the branched/cyclic alkanes, while the aromatic fractions contain the aromatics. The n-alkane solution and the aliphatic fraction of the composite solution biodegraded rapidly between day 0 and day 15 with a total measured loss of 65 % and 44 %, respectively. Degradation rates were slower between day 15 and day 35 resulting in a total loss for the n-alkanes of 72% and for the aliphatic fraction of the composite of 54 %. In contrast, the aromatic fraction showed no loss between day 0 and day 15, but subsequently biodegraded rapidly with a total loss of 46% by day 35. The branched & cyclic alkane solution and the aromatic fraction of the composite solution had the lowest rates of biodegradation throughout the experiment, with total measured losses of 28 % and 18 %, respectively.

Transformation Reactions of SRS-relevant Organics: 2. Enhanced Degradation of Halogenated Organic Contaminants by Redox-Manipulated Iron-Bearing Clays

Gary L. Mills, Will P. Gates, Valentine A. Nzengung and Reyna M. Castillo

Of the many instances of ground water contamination by organic chemicals at DOE sites, chlorinated solvents forming dense nonaqueous phase liquids (DNAPLs) are among the most pervasive and difficult to treat. The development of improved methods for the remediation of ground water contaminated by halogenated organic compounds during the past decade has emerged as a significant environmental priority. Due to the high cost and poor success of pump-and-treat technologies, the priority is shifting to *in-situ* methods. Current technologies under development for use in remediation of chlorinated solvent waste sites are enhanced pump-and-treat systems, *in-situ* bioremediation, and *in-situ* chemical treatment. Although significant progress has been made with the *in-situ* bioremediation approach, researchers are still frustrated by the requirement of intimate mixing between the contaminated ground water and solutions injected into the subsurface for the purpose of stimulating favorable biological activity.

Biotic and abiotic approaches have been suggested for reducing octahedral Fe(III) in

dioctahedral smectite to Fe(II) to create *in-situ* permeable barriers. Chemical (or abiotic) treatments to create reducing conditions in aquifer sediments have been chosen for our studies because the kinetics of the treatment process are faster than biological mechanisms and the system can be easily optimized and managed. The advantages of using dithionite over other reducing agents are: (1) dithionite is quite reactive as a reductant; (2) few side reactions occur; (3) dithionite and its reaction products are relatively nontoxic; and (4) the physico-chemical properties measured thus far for dithionite reduced smectites are of similar magnitude as biologically reduced smectites. Also, the unreacted dithionite can be cycled to reduce costs. As a result, dithionite is favored and has been recommended as a potential environmentally suitable reducing agent for structural iron in clay- and silt-sized layer silicates to artificially control *in-situ* redox conditions.

To offer a clearer understanding of the role of various geochemical properties on this process, the ferruginous materials selected for this study were well characterized reference clays. The influence of measured physico-chemical properties, including redox capacity, pH and Eh, Fe(II)/surface area, and mineralogy on the effectiveness of the redox-manipulated materials are being examined. This information will be used in part to evaluate if the selected ferruginous materials are potentially effective reactants for an improved cleanup technology. Understanding the role of these parameters in the reactivity of a sediment will also enhance our ability to predict and optimize the performance of this approach in field remediation practices. Our major goal is to manipulate redox conditions in ferruginous sediments to achieve optimum transformation rates for remediation of groundwater polluted with redox-sensitive chemicals.

The use of dithionite to manipulate the redox potential of sediments to enhance the reduction of reducible organics in groundwater is analogous to optimizing abiotic redox reactions that are operational in anoxic natural environments. In many groundwaters polluted with tetrachloroethylene (PCE), less oxidized chlorinated species (trichloroethylene, dichloroethylene, and vinylchloride) of the more oxidized parent compound are commonly detected. These dehalogenation by-products result from the biotic and/or abiotic reactions that are operational in the redox environments. The parent compound may not be mineralized in the course of these reactions because of the overall limited redox capacity of the reducing environments. The term redox capacity is used here as a measure of the number of electron equivalents which a sediment may donate or accept to reduce or oxidize a substance. This means that if the redox capacity of a sediment is known, then it is possible to estimate the amount of a given chemical it can reduce. This capability is useful in the design of cleanup strategies for polluted sites.

The sensitivity of tetrachloroethylene (PCE) reduction kinetics at the surfaces of Na-dithionite-reduced iron-bearing smectites (ferruginous smectite and Na-montmorillonite) to initial solids and dithionite concentrations was investigated in well-mixed, anaerobic laboratory batch experiments. At 25+2°C, measured heterogeneous reaction rates fit a pseudo-first-order kinetic model with calculated rate constants that depend upon smectite type, clay-water interaction, and initial aqueous dithionite concentration. The mechanism of inhibition is believed to be interference with the mass transfer of PCE to the smectite surface. The principal chlorinated degradation products identified were trichloroethylene (TCE), followed by much smaller amounts

of trichloracetaldehyde (TCAAD), dichloacetic acid (DCAA) and dichloroethane (DCA). At the conclusion of each kinetic study, mass balances based on PCE- and TCE-carbon were poor, suggesting other unidentified product(s). No significant degradation was observed in homogeneous dithionite anaerobic batch studies. Analysis of the Fe(II)/Fe(III) content of these clays showed that the amount of structural iron (III) reduced after reaction with dithionite was dependent upon ionic strength. The presence of structural Fe(II) was observed to reduce the availability of surface sites. Frequency shifts and the relative intensity change of infrared active octahedral OH stretching and bending modes were observed in the two Fe-bearing smectites as a function of structural Fe(II) content, and support the observed differences in rates of reductive dechlorination.

Stable Isotope Program

Christopher Romanek

Stable isotope studies were conducted to identify contaminants and their transformation products in complex environmental matrices and to trace their flow from seepage basins into uncontaminated aquifers at the Savannah River Site. Listed below are two notable sites, the M-area Seepage Basin and the D-Area Coal Pile Containment Basin.

M-Area Seepage Basin: Free-phase chlorinated hydrocarbon contaminants (e.g., TCE, DCE, DCA) and their aqueous counterparts were analyzed at the M-Area Seepage Basin to determine if chlorine stable isotopes ($^{37}Cl/^{35}Cl$) can be used as natural tracers for stimulated biodegradation procedures. Stable isotope ratios showed that chlorine can be traced from parental solvent into dissolved inorganic chloride and that this material can be discriminated from ambient chloride. This unique quality will permit the mass of degraded material to be determined unequivocally at leaky containment basins across the DOE complex.

D-Area Coal Pile Containment Basin: At D-area, shallow ground water is being contaminated by metals leaching from a coal pile into a nearby catchment pond called the D-Area Coal Pile Containment Basin. The natural processes of precipitation and evaporation at the site impart a unique stable isotopic signature to the waters at the basin ($^{2}H/^{1}H$ and $^{18}O/^{16}O$) that can be traced into the underlying water table aquifer that receives contamination. Mixing ratios are presently being determined for ambient and contaminated waters of the water table aquifer and the extent of natural attenuation or intrinsic remediation of contaminant metals will be determined.

In addition to work performed on the Savannah River Site, Dr. Romanek has generated outside funding for the Stable Isotope Program through collaborative efforts with researchers at the Johnson Space Center, NASA and various academic institutions in the U.S. and U.K.

Molecular Simulations of Contaminant Transport Processes

Brian J. Teppen

Insight into risk assessment and remediation requires the synthesis of data across scales, ranging from molecular-scale spectroscopic investigations, through lab-scale transport and extraction experiments, to field-scale plume migration studies. Both basic research and technology development will proceed faster as hybrid ideas are generated across scales. Within this context, molecular-scale information is a key to managing contaminated soils and sediments, because mechanistic understanding enables robust risk assessment, improves the chances of creating viable remediation technologies, and allows rational transfer of proven technologies to new environments. The AACES Environmental Computational Chemistry program strives to produce this molecular-scale information through molecular simulations of environmental systems. Molecular simulations are viewed as a complementary enhancement to experimental spectroscopic, diffraction, and imaging technologies that are other strengths of AACES. Therefore, molecular modeling capabilities are integrated into the broader AACES program, and have already proven useful to interpret experimental data, furnish mechanistic explanations, and predictively examine proposed remediation technologies.

Molecular simulations of organic compounds have been developed since the 1960's, and simulations of biomolecule-drug interactions are widely and successfully used in the pharmaceutical industry today. We are working to adapt molecular dynamics simulation methods to the study of soil mineral phases and their interactions with aqueous contaminants. To apply these modeling tools, the most important prerequisite is the development of accurate expressions for potential energy as a function of atomic positions. These expressions are important because the energy computed for a given atomic configuration is used to calculate the forces, which in turn determine the entire trajectory of the system. In order to assign parameters to these expressions (1) available experimental data and (2) high-quality quantum mechanical calculations on small mineral fragments are being used. As this database of experimental and quantum results grows, our parameter set continually and systematically improves. At each stage of development, molecular dynamics and Monte Carlo simulations are performed to test the model against experimental data. With this model validation, simulations of applied systems may be undertaken. Our goals are to develop more robust models for environmental colloids and to use the models to predict a greater variety of kinetic, thermodynamic, and structural information.

Validated, dynamic molecular models have been created for the clay minerals, which tend to be the most reactive phases in soils and aquifers. They provide a unique and powerful tool for exploring the atomic-scale interactions between DOE priority contaminants and subsurface aquifer materials. This work is complementary to two other environmental molecular modeling groups within the DOE complex. We shared our force field methods with Dr. Randy Cygan at Sandia National Lab and we co-authored a proposal with Dr. David Dixon within the Environmental Molecular Sciences Laboratory at Pacific Northwest National Lab.

Our current research program has two major thrusts. First, simulations of practical geochemical systems in order to obtain missing information that is needed for risk assessment and remediation of DOE sites. Within this category, our efforts include:
(1) Simulations of Dense Non-Aqueous Phase Liquids (DNAPL's) such as Trichloroethene (TCE) and Tetrechloroethene (PCE) interacting with SRS colloids to determine partitioning mechanisms and transport parameters. These results will enable accurate prediction of DNAPL plume migration and the fates of sorbed DNAPL's.
(2) Simulations of radionuclides such as Cs^{+}, Sr^{2+}, and UO_2^{2+} and oxyanion contaminants such as chromate and arsenate. Molecular modeling allows precise investigation of metal and actinide speciation in complex solutions. Such data are urgently needed to create cost-effective remediation strategies for mixed-waste plumes, but are difficult to determine experimentally.
(3) Simulations of "designer" sorbents, to explore new technologies for enhanced waste isolation/stabilization. Molecular simulations can screen sorbent interactions with a wide variety of contaminants in greater detail, at far less cost, and more quickly than experimental methods.
(4) Field-scale solute transport models are required for expedited plume characterization, risk assessment decisions, and choices of remediation technology. Transport parameters for these models can be estimated from molecular simulations, thus avoiding expensive experimental determination of the parameters for each contaminant at each plume site.

The second major thrust of our research program is the development and validation of molecular models for a greater number of relevant environmental surfaces such as the aluminosilicates that are a subset of the clays. Currently, we are testing an extension of the "force fields" to more clays including the montmorillonites, vermiculites, and nontronites, as well as the iron oxides is being tested.. Within the next year, validated molecular models should be developed for every major colloidal solid phase found in SRS soils, aquifers, or sediments.

Two sessions of a short course were taught through AACES in 1996. The course, "Introduction to molecular modeling for the environmental sciences," was first presented May 30 through June 1 to nine researchers. People from the Netherlands, New Mexico, Idaho, Texas, Georgia, and three different SC universities participated. The second session was offered on September 24-25 for local site personnel. Again, nine attended, representing local DOE and WSRC.

A contract was established between the University of Georgia and a major oil company in June 1997. Besides their importance in controlling contaminant transport and fate, clay minerals are crucial in both finding and obtaining petroleum energy resources. Exxon determined that our approach is the only modeling methodology that could reproduce a wide range of experimental data, and agreed to provide personnel and computer time to speed up the expansion, validation, and application of these techniques.

B. Ecological Stewardship

Most (90%) of the SRS is not industrialized or directly contaminated. 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. Decommissioning of facilities, such as shutting down the river water distribution system, will also have an effect on the landscape. Management of SRS lands requires data-intensive research and monitoring that provide meaningful recommendations on land stewardship to minimize ecological risk and promote ecosystem health. This program includes research relevant to ecological land management and stewardship, and provides advice to 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 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*
- *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 by bringing our knowledge base to the table*
- *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*
- *Interface with other SREL groups, SRS groups and professionals from other DOE sites to develop workshops that explore and establish new approaches to land use and ecological risk assessment*
- *Develop with DOE and other SRS groups, a mutually acceptable definition and conception of ecosystem management.*

Carolina Bay Hydrology and Vegetation

Beverly S. Collins

The marsh vegetation of herbaceous Carolina bays is made up of floating-leaved perennials and emergent annuals and perennials. From year to year, composition of the vegetation is influenced by interaction of bay hydrology with the seed and propagule bank. The seed and propagule bank is a potential community. Timing and duration of bay filling and drawdown determines extant vegetation. Long periods of flooding could promote vegetative spread of perennial plants, while drawdown could promote germination from the seedbank.

The interaction of Carolina bay hydrology with the vegetation and the seed/propagule bank was investigated from 1994 to 1997. The general objective was to determine how hydrology influences clonal spread of perennial plants and germination from the seed bank. Six Set-Aside herbaceous bays were studied: Mona Bay, Woodward Bay, Craig's Pond, Sarracenia Bay, Dry Bay, and Ellenton Bay.

In winter 1994, soil cores were removed from each bay from points within the bay that have a 90%, 75%, 50%, or 25% chance of being flooded in any given year. Cores were placed in flooded or unflooded conditions and the vegetation arising from each was censused over the 1995, 1996, and 1997 growing seasons to determine (1) if the distribution of seeds and propagules reflects hydrology; (2) if the vegetation reflects the seed/propagule bank; and (3) if the contribution of the seed/propagule bank varies with hydrology. Seedbank and vegetation relationships were examined by censusing vegetation in the bays during 1995 and 1996 at the core sampling points.

After two years, the number of plant species from the cores differed among bays and water level treatments, but not among sampling points. Unflooded cores were most rich and flooded cores least rich. The plant community from flooded cores was primarily floating-leaved aquatic herbs and perennial emergent grasses. Unflooded cores had few floating-leaved plants and were a mix of wetland grasses, sedges, and herbs. Bay vegetation differed among bays and among sampling points. Likely flooded points near a bay center had no vegetation or floating-leaved aquatic plants. Least likely flooded points far from the bay centers had a larger component of upland vegetation, and intermediate points had aquatic and emergent vegetation. Vegetation from the propagule bank appears to reflect the duration and depth of spring flooding, and is not zoned. Bay vegetation is zoned with increasing distance from the center of the bay.

Fire and Sandhills Vegetation

Beverly S. Collins and Stephanie Foré

Fire has formed the sandhills vegetation. With fire suppression, plant composition slowly shifts toward an oak-dominated forest. This slow process can be reversed by fire. Fire has been experimentally reintroduced into several stands at the Sandhills Fire Site Set-Aside. Plots initially

burned in the early 1980's were reburned in winter (1993) or summer (1994); a control area was left unburned. The plots were sampled before the burn, and are being resampled the first, third, and seventh year after burning to monitor vegetation response. The winter burn was resampled in summer 1994 and 1996; the summer burn was resampled in 1995; the control area was resampled each year. In general, burning decreases the density of mature trees, increases the density of vegetative shoots, and increases the density of grasses and forbs. Vegetation is less clumped following burning. In spring 1997, an accidental, uncontrolled fire burned through the experimental plots. Vegetation response to this fire is being monitored during the 1997 growing season.

To determine if vegetation response to fire reflects seed bank response to burning or nutrient release by fire, seedbank samples were taken and monitored in a greenhouse. The sandhills seedbank is sparse, and burning on fertilized seedbank samples did not recruit new vegetation from the seedbank. However, grasses common to the sandhills have >50% germination when not water limited. These results suggest that seed density, not germinability, limits regeneration in the sandhills.

To determine if vegetation development following fire is related to an individual plant's ability to acquire nutrients liberated by the fire, three common grasses are being tested during the 1996 and 1997 growing seasons for the timing of nutrient uptake and ability to take up low or high nutrients in different spatial patterns. At the end of the 1997 growing season, plants will be harvested and their nutrient content will be analyzed and related to the experimental treatments.

To determine if genetic and growth response of a common clump-forming sandhill shrub, *Vaccinium staminium*, is altered by fire, clumps were censused before and after the summer burn. Some clumps increased in size after burning, some decreased, and some did not change. Genetic analyses revealed that most clumps are composed of more than one genotype. Additional research is needed to determine how different genotypes respond to fire.

Vegetation Development and Contaminant Uptake in Par Pond

Beverly S. Collins, Tom G. Hinton, and Rebecca R. Sharitz

Management strategies, such as the decision to refill Par Pond, the choice of input water, and the maintenance of stable or fluctuating hydrology, influence vegetation development and contaminant transport. To determine the influence of water source (Par Pond, Pond B, Savannah River) and hydrology (stable, fluctuating) on development of vegetation from the seedbank and on radiocesium transfers among sediments, macrophytes, and water, sediment cores were removed from the original waterline at 13 locations around Par Pond. Cores were placed in pots and given a water source and hydrology treatment for one growing season. Plant species composition in the pots was censused at the end of the 1995 growing season. Water source and hydrology affected plant cover. Vegetation from cores in Savannah River water had highest cover while vegetation from cores in Pond B water had lowest cover. Vegetation from continuously flooded cores had lowest cover; cores

that were drawn down produced highest cover. The plant community from continuously flooded cores was distinct from drawn down or moist cores. Plant samples and samples from pot sediments are being analyzed for radiocesium content.

Endangered Species

Philip M. Dixon

The endangered species program seeks to understand the demography and life history of rare plants on the Savannah River Site, and thus help management make decisions. The primary concern is with *Echinaceae laevigata* (smooth purple coneflower), a federally endangered species. Two populations of this species on the Savannah River Site are censused annually in the early fall. As in previous years, there was considerable turnover in the larger population on Road B-9. Both mortality and establishment rates are high. The smaller Burma Road population continues to decline. In the fall of 1996, it contained only 138 plants, a loss of 8 from 1995. There is now sufficient data to make a preliminary evaluation of the effects of the management experiment conducted at the Burma Road site. In early 1994, the Burma Road site was divided into four parts. One was left untreated as a control. One quarter was burned (spring burn), the tree canopy was removed from above one quarter, and the fourth quarter was both burned and cleared. There are no statistically significant effects of any management treatment on the survival, establishment, or growth of *Echinaceae*, in large part because of considerable plant-plant and year-year variation. Analysis of the population dynamics using a matrix projection model suggests that population growth rate is most sensitive to the survival and growth of adult plants. This provides some hope for the population. In 1995 and 1996, the average size of surviving plants increased in all experimental treatments. This reverses a long-term trend of decreasing size since 1988. Year-year variation in weather may be the most important factor influencing the success of the Burma Road population.

Improved Quantitative Techniques

Philip M. Dixon

This research program develops better statistical methods to analyze environmental and ecological data. Instrumental imprecision and chance variation are components of every measured environmental quantity. Statistical analysis seeks to extract accurate conclusions from imprecise data and to quantify the uncertainty about those conclusions. Better statistical methods provide two benefits for environmental restoration and remediation: (1) more accurate conclusions from limited data and (2) less data needs to be collected to reach sufficiently accurate conclusions. Our work concentrated on four projects: the assessment of spatial patterns, the analysis of change in species composition, the analysis of data with below-detection limit values, and the construction of statistical tests for no effect.

Spatial patterns have many consequences in population biology and ecology. For example, trees damaged or blown over by high winds may be randomly located or concentrated into clusters, creating large gaps. A new statistical technique for the clustering of event locations has been developed. This technique is 2.5 times more efficient than alternatives. This means either that smaller differences in spatial pattern can be detected, or that smaller sample sizes can be used. This clustering technique has been used to analyze foraging sites for wood storks.

The second project continues the development of methods to analyze the effect of environmental change on plant and animal communities. Extant methods are adequate for analyzing trends in simple variables such as temperature or pH, but not for complex variables such as species composition. Good, statistically powerful techniques for detecting trends in species composition could be used to identify low level, chronic effects of SRS operations before such effects create obvious and expensive problems. Because species composition will change even in the absence of impacts (e.g., succession), some form of calibration is required to infer potential impacts and predict subsequent ecosystem consequences. During the past year, these techniques have been applied to evaluate changes in zooplankton communities in Pond C and has been extended to more complex experimental designs to assess plant community responses to disturbance.

Most statistical methods for below-detection limit data are descriptive: they estimate the mean or median, but do not quantify the precision of that estimate. Most environmental assessments also require statistical inference , e.g., a confidence interval or hypothesis test. We have shown that standard statistical techniques (e.g., t-tests or likelihood ratio tests) are not appropriate when there are a lot of below-detection limit values. We are in the process of evaluating a recently proposed non-parametric technique based on Theil-Sen regression. However, computer-intensive techniques can be used accurately to estimate confidence intervals or test hypotheses. These techniques have been applied to SRS water quality data, but they are applicable to any data with below-detection limit values.

In the final project statistical techniques are being developed to test hypotheses about no effect. The traditional statistical hypothesis test evaluates whether the data provide sufficient evidence to reject a working hypothesis, that there is no difference between two groups. One common environmental application is the comparison between a background area and a putative contaminated area. Failure to reject this hypothesis of no difference does not mean that the two areas have the same concentration. Techniques that reverse the usual hypothesis test are being developed and assessed. Two areas are assumed to be different unless the data provide good evidence that they are similar. These tests have been applied to compare contaminated areas with background areas, to evaluate the effect of a putative source of contaminants, and the consequences of moving a water quality monitoring station. These tests have been extended to evaluate the evidence for amphibian decline.

A Large-scale Experimental Approach to Determine the Effects of Coarse Woody Debris on the Species Richness and Relative Abundances of Amphibians and Reptiles on the Savannah River Site

Michael E. Dorcas, Justin D. Congdon, and J. Whitfield Gibbons

One of the most important components of proper management of forested lands is determining the habitat requirements of animals and how their habitat is affected by specific management practices. Harvesting and utilization of woody materials may significantly alter animals' habitats and thus impact species richness and relative abundances. Depending upon the intensity and frequency of thinning and factors affecting the mortality of trees, the amount of coarse woody debris (greater than 4-6 inches in diameter) at any given site will vary. Coarse woody debris (CWD) may have significant, and potentially beneficial, effects on populations of amphibians and reptiles inhabiting the area. The presence of CWD may provide important retreat sites with suitable thermal and hydric conditions for many species amphibians and reptiles. The presence of CWD may also provide an increased diversity and abundance of invertebrate and vertebrate prey for many species of amphibians and reptiles.

The USFS (Athens and Savannah River Forest Station) has established and will maintain four replicated experimental plots (approximately 15 ha each) on the Savannah River Site (SRS) during the Summer of 1996 in which CWD is controlled in specific ways to facilitate integrated research to determine the potential role of CWD as a key resource. The following treatments have been agreed upon after considerable consultation between researchers at SREL, SRFS, UGA, Clemson University, and the USFS (Athens):

1. A control in which CWD is not manipulated.
2. Removal, in which all of the woody debris (anything greater than 4 inches in diameter) is removed, including standing snags. This treatment will be maintained for three years, after which, it will be available to be used as an augmentation treatment.
3. Removal, in which all of the woody debris is removed, except for standing snags.
4. A control as described in treatment number one for a baseline period (3 years), then extensive felling to simulate a catastrophic wind-fall that would result in a large pulse of CWD.

The SRFS has established four replicates of the four treatments in similar stands (loblolly pine) on the SRS. Each set of replicates is at least 200 meters from any wetland or primary road. The SRFS will maintain all treatments with some restrictions to allow thinning and burning operations at preplanned intervals. However, all management operations will be conducted at the same time on all plots so that all plots experience similar levels of disturbance at the same times.

The overall goal of the research described here is to determine the effects of CWD on the species richness and relative abundances of amphibians and reptiles on the SRS. The results of this research will be of benefit to the USDA Forest Service, SRS Forest Service, the Forest Service in Athens, and the commercial wood products industry by increasing our knowledge of how

amphibians and reptiles respond to CWD. The results of these studies should be very important when considering the effects of CWD during the development of management plans for forested lands.

Our approach is to use drift fences with pitfall and funnel traps to determine the species richness and relative abundances of amphibians and reptiles. We have constructed four drift fences (each 30 meters long) with pitfall traps and funnel traps to sample amphibians and reptiles in all of the control and removal plots (treatments 1 and 3 above). Each drift fence has one pitfall trap at each end and a pair of pitfall traps, one on either side, in the center of the fence. Two pairs of funnel traps, one on each side, are positioned at 10 meter intervals along the drift fence. The pitfall traps are used to capture salamanders, anurans, lizards, and small snakes. The funnel traps are used to capture larger snakes, lizards, anurans, and salamanders. The drift fences are set out in perpendicular arrays in the center of each treatment plot to capture animals moving in all directions. We were able to complete installation of the drift fences in September 1996 when the SRFS contractor completed their initiation of the treatments (i.e., removal of all CWD in the removal plots). To optimize the sampling time of year and to allow the treatments to begin to have an effect on herpetofaunal diversity and abundances, we sampled for three months in the Spring of 1997 (i.e., March through May). We sampled during this time using the drift fences every day on alternate weeks (i.e., one week on, one week off). When captured, amphibians and reptiles were identified to species, counted, and marked (either toe-clipped or pit-tagged) to allow us to determine species richness and relative abundances. Data analysis is continuing, but preliminary results indicate that variation among the treatment plots will overshadow any differences attributed to the effects of CWD removal. More extensive studies, in collaboration with Dr. Josh Laerm at the University of Georgia, will be conducted in the near future (1997-1998) to further examine the potential long-term effects of CWD on amphibians and reptiles.

In addition to providing important basic information on how the structural environment affects populations of amphibians and reptiles, the results from the above research will be of benefit to the USDA Forest Service, SRS Forest Service, the Forest Service in Athens, and the commercial wood products industry by increasing our knowledge of how amphibians and reptiles respond to CWD. The results of these studies should be vital when considering the effects of CWD during the development of management plans for forested lands.

Population Dynamics of Turtles

J.Whitfield Gibbons

Knowledge of the basic ecology of turtles has been applicable to a variety of environmental issues of importance to DOE, and such studies continue both in DOE Set-Aside areas and other habitats on the SRS. SREL research on the population dynamics and ecology of freshwater turtles was initiated on the Savannah River Site in 1967 and has continued uninterrupted since that time. This research has subsequently become recognized nationally and internationally as one of the

longest continuous field ecology studies on natural populations of long-lived vertebrates in the world. The studies have been important in determining basic ecological information on the demography, life history, and ecology of freshwater turtles of North America in general and the Savannah River Site in particular.

The importance of peripheral terrestrial habitats has continued to be investigated this past year at the Dry Bay Set-Aside with the tracking of a cumulative total of more than 300 semi-aquatic turtles onto land. Their behavior in response to the former clearcut area on the south side of the bay suggests that such habitat may be unfavorable for turtle hibernation sites for several years following disturbance. We also have examined the nesting habits of the chicken turtle, which is a protected species in some parts of its range, in an effort to establish appropriate conservation guidelines for the species. Because turtles are excellent indicators of both radioactive and non-radioactive contamination as well as of landscape disruptions such as clearcutting, the acquisition of basic ecological data will serve as a foundation for assessing impacts on habitat alteration and certain forms of pollution to natural systems and should prove applicable to many of the environmental issues of concern to DOE on the SRS. Turtles will continue to serve as a biological monitor of radioactive and other contaminants and in the determination of whether free-ranging wildlife can incur genetic damage from contaminated sites. The continued long-term survey and research of particular habitats permits natural population fluctuations and response to natural stresses to be revealed.

Amphibian and Reptile Ecology

J.Whitfield Gibbons

The general objective of these studies is to acquire baseline information on the basic ecology, life history, and distribution patterns of all species of reptiles and amphibians known from the Savannah River Site. In-depth population studies are conducted on selected species whose abundance in particular locations make them tractable for this purpose. A general objective is to determine distributional patterns of all SRS species of herpetofauna on the site and to establish community composition of reptiles and amphibians at particular sites and habitats. The initial surveys for reptiles and amphibians on the Savannah River Site were made in the early 1950's when the area was first set aside for the production of nuclear materials. An additional survey was made in the mid-1960's by a University of Georgia graduate student at SREL. Since 1967, long-term records have been kept of the population status, distribution patterns, and general ecology of all species of reptiles and amphibians known from the site. The projects have resulted in the publication of more than 100 technical articles in scientific journals, the publication of two books that focus specifically on SRS species, and the preparation of numerous official reports for use by DOE. The long-term nature of the studies has resulted in the discovery of 20 species of reptiles and amphibians not reported to be present in surveys conducted in the the 1950's and the finding of two species (the pine woods snake and Florida mud turtle) not known formerly from this region of South Carolina. The gopher tortoise, a federally protected species in some parts of its range, was found on the SRS

in 1996. This finding indicates that, despite extensive research on the herpetofauna, many of which are extremely secretive, sensitive species may be present that we are unaware of.

Turtle Population Dispersion

J.Whitfield Gibbons

The original objectives were to determine the site of origin of the radioactive animals discovered on the SRS by SREL, establish the dispersal patterns of individuals which may have traveled over land to other aquatic habitats, and to understand the basic radioecology of turtles. The program has been useful from a research perspective by contributing to a basic understanding of radioecology in turtles, augmenting the information on dispersal patterns of slider turtles, and developing the use of flow cytometry as an analytical technique, one which is now used for other organisms living in radioactively contaminated habitats.

During the past year we continued to sample diamondback terrapins in the Kiawah River (control site) in preparation for analysis of contamination with those from the lower Savannah River, which might reveal long-term accumulations of radioactive materials from the SRS. We expect to provide a sufficient comparison of the uptake of various chemical and radioactive contaminants between the control population of diamondback terrapins and those in the lower Savannah River to establish whether residual radioactivity is present in the Savannah River estuary. We have also continued to monitor all turtles captured on the SRS for radioactive contamination and during the past year have continued to find free-ranging individuals that were significantly above background. Our intent is to examine the entire data set for the purpose of compiling a report on the history of radioactive turtles on the SRS.

Herpetofaunal Biodiversity Studies on the SRS

J.Whitfield Gibbons

The southeastern region of the United States has the highest overall biodiversity of reptiles and amphibians in North America, and more research on herpetofauna has been conducted on the SRS than any other site in the country. Research to assess the reality of global climate change in response to anthropogenic effects is in progress on a worldwide basis. One important measure is biodiversity because the numbers and relative abundances of species inhabiting an area are a consequence of a variety of historical and current environmental factors, and biodiversity can be an indicator of human-caused effects if natural fluctuations in biodiversity can be determined. In an attempt to take advantage of the long-term herpetofaunal research programs on the SRS, analyses were completed and a major scientific paper was published using the SRS as a model for determining herpetofaunal biodiversity. The effort involved data management and analysis of more than one million captures of reptiles and amphibians during the parts of five decades. The paper in *Environmental Management* should serve as a guide to sampling protocols and interpretation of

survey records for other DOE sites and other government agencies and has been requested by a wide variety of ecologists both nationally and internationally. We have also continued to census herpetofaunal diversity through the use of drift fences with pitfall traps, coverboard arrays set in a variety of habitats (including Set-Aside areas), and a variety of other standard herpetological techniques. The herpetofaunal biodiversity studies will provide a solid foundation on which to assess a variety of impact issues, such as forest management and cleanup programs.

Pen Branch Restoration Project

J Vaun McArthur

Restoration of Pen Branch is a project involving researchers from USFS, University of South Carolina at Aiken, Auburn University, Clemson University, and SREL. During last year we completed our initial sampling and survey of macroinvertebrates. Monthly samples were collected from artificial snag samplers and from the macrophyte beds along the stream. These samples have been processed and represent the best macroinvertebrate database from Pen Branch. In addition to the faunistic studies, dissolved organic carbon samples were collected and estimates of primary production based on chlorophyll a concentrations were made. All wood and macrophyte beds were mapped and measured to estimate their respective impacts on the stream. A planned large scale manipulation was not begun, as funds for artificial canopy construction were insufficient. As an alternative a new study using six artificial streams was initiated. These streams, located at SREL's Aquatic Ecology Laboratory will allow us to determine factors that increase macroinvertebrate colonization of streams. This design will investigate the roles of wood, flow, fish, canopy closure, and other factors on macroinvertebrate dynamics and provide meaningful trajectories to indicate stream recovery.

Actinomycete Ecology and Antibiotic Resistance

J Vaun McArthur

Actinomycetes are bacteria that are the primary decomposers of chitin, a very abundant natural biogenic compound. In addition, Actinomycetes are important sources of antibiotics. Very little is known about the factors that control their distribution and abundance, i.e., their ecology. Last year a survey of Actinomycetes was initiated in several streams on the SRS identifying several novel groups. Laboratory experiments designed to observe interactions among true fungi and actinomycetes have shown that these organisms are very antagonistic. In fact, no fungi survive for more than five days under our experimental conditions. These data indicate strong antibiosis and may indicate novel fungicidal properties. Given that genes that confer antibiotic resistance are often found on plasmids (mobile strands of DNA) along with genes to break down complex xenobiotic compounds and that these genes can be transferred among totally unrelated taxa, we hypothesize that the frequency of antibiotic resistance increases along contamination gradients. Since antibiotic resistance and reemergence of infectious diseases is occurring, this hypothesis suggests that

contamination of the environment may increase the spread of disease resistance. Understanding both the transfer of resistance genes and the distribution of groups such as the Actinomycetes, which may have unique antibiotic capacities, provides information important to both environmental clean-up and biomedical research.

Manganese and the Growth of Water Tupelo and Baldcypress

Kenneth W. McLeod and Thomas G. Ciravolo

Manganese is an essential micronutrient whose normal leaf concentration ranges from 20-500 mg/kg. However, concentrations in some tree foliage may range as high as 5000 mg/kg. Black gum (*Nyssa sylvatica var. sylvatica*) leaves ranged from 25-1500 mg/kg (ash), or approximately 1.25-75 mg/kg (dry weight). Manganese toxicity in forest trees is rare but is cited as a possible cause for tree mortality of swamp tupelo *(Nyssa sylvatica var. biflora)* in a wetland located on the Savannah River Site. Manganese also becomes more toxic as the soil environment is reduced, a normal occurrence when the soil is saturated with water. Although water tupelo (*N. aquatica)* and baldcypress *(Taxodium distichum)* cohabit the Savannah River swamp, water tupelo had much higher leaf Mn concentration: 2284 vs 198 mg/kg, respectively.

The objectives of this project include: 1) determining the toxic threshold value for leaf Mn concentration in water tupelo and baldcypress, and 2) determining if the observed disparity in leaf Mn concentration between baldcypress and water tupelo continues when grown in a Mn enriched substrate.

Seedlings of both species were grown in fertilized potting soil kept at saturated to slightly flooded conditions in the greenhouse. Manganese (as a manganous sulfate solution) was added to the pots at rates of 0, 40, 80, 160, 320, or 400 mg/kg Mn based on 10 kg soil. Water in the pot was neutral to slightly alkaline (pH of 7.0 to 7.8).

Growth parameters of baldcypress were unaffected by Mn treatment. Height, diameter, number of side-shoots, total biomass, total leaf mass, and main stem mass of water tupelo were significantly ($p > 0.05$) affected by treatment. Treatments greater than 160 mg/kg had significantly less growth than in the 0 mg/kg treatment. Total biomass of the control plants was greater than two times that of the highest Mn treatment. The number of side-shoots tended to increase with greater Mn treatments. Leaf Mn concentration was greater in water tupelo than in baldcypress for all but the highest treatment. In both species, leaf Mn concentration tended to level off after 160 mg/kg treatment.

Leaf Fe concentration in the three highest Mn treatments was significantly less than the controls for water tupelo but only the highest Mn treatment differed for baldcypress. Leaf Fe concentrations were reduced approximately ten times in both species at the highest treatment. Two of 21 water tupelo seedlings with leaf Mn concentration >4000 mg/kg and all those below 3000

mg/kg had little or no leaf damage. This variability may allow the selection of Mn tolerant individuals. However, it remains to be seen whether nonsexual reproduction of this species is feasible and if Mn accumulating ability would be passed on to propagules.

The highest mean leaf Mn concentration in baldcypress was 4600 mg/kg and growth was not adversely affected. Thus, baldcypress may be more useful than water tupelo in phytoremediating Mn contaminated sites.

Ecological Risk Assessment and Stream Restoration due to Thermal Flow Disturbance

Gary K. Meffe

The effects of effluent release on fish community structure and function are being addressed using Fourmile Branch and Pen Branch as replicate sites impacted by past thermal effluents and current flow augmentation, and Upper Three Runs Creek and Meyers Branch as replicate control sites. Fishes in these streams are being studied at several levels of organization, including community structure, interspecific interactions, species-specific habitat use, and individual physiology.

Community and Habitat Alteration Due to Past Thermal and Flow Disturbance. Intensive sampling of stream fish communities and habitat structure began in these four streams in 1994 and has continued to the present. To date, ten seasonal samples have been taken at 55 sites, which were chosen to include major habitat types in the selected reaches of each stream. Surveys consist of multiple-pass electroshocking, identification and counting of collected individuals of all species, measurement of individuals of most species, and return of fish alive to the stream. To date, over 89,000 fish have been collected. Surveys were conducted in January (winter sample/ prespawning for early season spawning fishes), May (pre-spawning for summer spawning species/post spawning for early spawners), and September (post spawning for summer spawning species). Taking collections during these times maximizes the utility of our data for examining demographic patterns and seasonal patterns of habitat use.

Within each of the 55 sites, at least five permanent habitat transects were established, upon which detailed information is collected, including channel dimensions, depth profiles, channel erosion and sedimentation patterns, substrate types and firmness, presence and type of woody debris, presence of submergent and emergent aquatic vegetation, canopy cover (amount and type), water velocity, pH, conductivity, and dissolved oxygen. Our constant elevation markers help determine stream bed scouring and sediment deposition over time. Sediment loads in the water columns of each stream during flood events are also analyzed.

An interdisciplinary team is comparing carbon cycling and functional organizations of riparian/stream communities among impacted and ambient streams. Linkages among riparian

vegetation, physical condition of the stream, and interactions among stream biota are being examined. Michael Aust and Laura Giese of Virginia Polytechnic Institute are documenting carbon pools in standing vegetation, litter falls, and decomposition rates. Graeme Lockaby and John Wigginton of Auburn University are investigating carbon and nutrients in riparian soils, and Randy Kolka and Carl Trettin of USDA Forest Service are investigating carbon and nutrient movement in the ground and surface waters. J Vaun McArthur and Michelle Lakly of SREL are aiding by measuring surface water levels of carbon and nutrients and additional primary production parameters such as algal biomass. They are also examining diversity, assemblage structure, functional feeding groups, abundance and productivity of aquatic invertebrates in two streams. Our work is examining secondary production of fishes, spatial distribution of aquatic macrophytes, wood debris, stream sediment and detritus, canopy development, and changes in stream geomorphology. Overall, we will be able to compare carbon sources and availability, and the consequential transfer through aquatic invertebrates to fishes, among streams impacted by past thermal effluents and unimpacted systems, and the effects of the persisting physical environment on these transfers.

Analysis indicate that the disturbed streams have at least as many species of fish as control streams, and two to five times the densities of individuals. However, impacted streams are heavily dominated by a few groups of fishes, including suckers, mosquitofishes, minnows, and sunfishes, which are characteristic of disturbed areas. Control streams have a more even distribution of species, characteristic of natural sites. Also, diversity and evenness indices are significantly higher for control sites, indicating that community structure of disturbed streams reflects the long-term disturbances they experienced.

Responses of Community Structure to SRFS Restoration Activities. The Savannah River Forest Station has divided the disturbed Pen Branch stream corridor into a series of cross-sections that mark unmanipulated control areas and experimental restoration sites. The experimental areas have been herbicided to kill existing vegetation, burned to remove ground cover, and replanted with native hardwood trees. Twenty-seven of the 55 study sites are distributed among these control and experimental sections of Pen Branch, and allow analysis of the effects of restoration efforts on the fish communities and the ecosystem. Data collected prior to vegetation manipulation have established a baseline of fish communities before experimental restoration, and data from undisturbed streams are serving as a target endpoint of a successful restoration. Our current data collection examines the short-term effects of the restoration process as well as establishing an early trajectory of the recovery process. Analysis indicates that removal of the low willow/shrub canopy has greatly increased aquatic macrophyte and fish abundance in the restoration areas. Long-term monitoring will be required to record the ultimate effectiveness of the restoration efforts.

Mechanisms Influencing Community Composition. Several mechanisms that influence or control community structure are being examined in detail:

Habitat shifts and spawning needs of individual species: Habitat shifts and seasonal spawning movements of individual species for all stages of their life cycles are pertinent both to understanding community function and to monitoring recovery toward endpoints. Seasonal and

ontogenetic habitat changes are being examined for an array of species. Spawning and nursery areas, as well as over-wintering areas, are being identified for *Lepomis auritus* (red breast sunfish), *L. punctatus, L. marginatus* (dollar sunfish), and *Notropis cummingsae* (dusky shiner), four common species in these streams. Habitat shifts by individual species then will be compared among the four study streams, and the tolerance of individual species to habitat modification determined.

Interspecific spawning interactions and demography of selected species: Dusky shiners migrate into slow, still waters to spawn on nests of redbreast sunfish , and the interaction is probably obligatory for the shiner. Also, while in the host sunfish nests, the shiners feed on embryos and larvae, selectively eating host offspring: (1) documenting stream-wide patterns of nesting activities as a function of previous disturbance (braided, disturbed streams vs. natural, undisturbed streams) and local habitat structure; (2) comparing microhabitats of individual nests and their placement among mesohabitats within and among streams by beginning to characterize the local habitat structure (canopy development, aquatic vegetation, woody debris/cover, substrate type, water depth, temperature, distance to moving water, pool characteristics, and surrounding land use), size of nests, nest activity, distance from shore, and coloniality; and (3) using the number of nests observed in our study sites along with our community data to analyze demographic patterns of these species. All of these studies began in 1995 and are in progress. Additionally mating systems of redbreast sunfish are being examined using microsatellite DNA to determine parentage in collaboration with Dr. John Avise of the University of Georgia. Parental fathers, potential cuckolders, potential mothers, and offspring were collected along with meso- and micro-habitat data. Subsamples have been processed and sent to John Avise for microsatellite DNA analysis. Laboratory processing of the remaining samples and adult fish is in progress. These data will allow comparison of spawning and reproductive success of parental vs. cuckolding males and examine the role of each and their interactions in maintaining viable populations. Characteristics of parental males and their nests will be compared to parental male spawning and reproductive success, and rates of cuckoldry. The current DNA work with redbreast sunfish could lead to a phylogenetic/ecological comparison. Patterns of resource allocation (among somatic growth, sexually dimorphic development, testes mass and fat storage) in response to breeding strategy will be investigated.

Physiological Responses. Monthly collections of dusky shiners were made in the four streams to study their growth, lipid storage, and size and reproductive patterns as a function of the systems in which they occur. Samples are being processed.

Freshwater Mussels of the Savannah River Site

Margaret Mulvey

Freshwater unionid mussels are one of the most endangered faunal elements in North America (Master 1999, Williams et al. 1992). The Savannah River adjacent to the Savannah River Site (SRS) and streams draining the SRS provide habitat for populations of freshwater mussels

which are rare (Britton and Fuller 1979, Davis and Mulvey 1993) and which may be of concern to SRS operations. The genus *Elliptio* is represented by at least ten species. Our efforts are directed to the clarification of the occurrence and distribution of these species on the SRS, in South Carolina and throughout the Atlantic Slope. This broad effort is necessary to evaluate the status of local species. To determine genetic differentiation among species and relationships for rare mussels, we have used allozymes, DNA sequencing, and DNA restriction fragment length polymorphisms. We have presented the first complete DNA sequence for the 18 kilobase pair ribosomal array of *Elliptio* and five other freshwater mussels. DNA sequence data for the cytochrome oxidase subunit I gene has provided evidence that there are several currently unrecognized species of anodontine mussel in this region. During the course of this study, we have identified a previously undescribed pattern of mitochondrial inheritance in *Pyganodon gibbosa*. These genetic studies continue to show that problems with species nomenclature can be addressed with the genetic data and that the biodiversity of the freshwater mussel fauna in this region has been underestimated.

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Evaluating Drought Stress In Longleaf Pine Plantations Using Remote Sensing Technologies

John E. Pinder, III

To expand the potential habitat for the endangered Red-Cockaded Woodpecker, the Savannah River Forest Station is developing tracts of land as long-rotation, longleaf pine plantations. Because some of these stands are being planted on soils that represent the dry end of the natural distribution of longleaf, a major limitation on the success of these plantations can be prolonged summer drought. Episodes of prolonged summer drought have occurred in recent years, most notably in 1990 when the lowest annual precipitation in the last 50 years was observed. To evaluate the effects of the 1990 drought on longleaf pine growth, a research project was initiated to determine the relationship between measures of drought stress derived from Landsat Thematic Mapper data and the growth rates of longleaf pines measured using analyses

of tree ring widths.

Landsat Thematic Mapper data (TM) summarizes the reflectance of solar radiation from the ground surface for 3 visible and 4 infrared bands in 30-m x 30-m areas of ground surface termed pixels, and drought stress is indicated by the ratio of infrared reflectance between bands 4 and 5. Where leaves have a high water content, the reflectance in band 5 is much lower than that in band 4. Where leaves have a low water content, the reflectance in bands 4 and 5 are similar. Thus, larger ratios of band 5 to band 4 indicate drought stress. Because the ratio of band 5 to band 4 can also be affected by spatial variation in the density and orientation of leaf surfaces, multiseasonal acquisitions of TM data were used to normalize the ratios observed in the drought months of June, July and September 1990 to those observed for the same pixels after periods of heavy rain in November 1989 and November 1990.

The TM data for June and July indicated significant drought stress that varied among soil types and among timber management units. The ratio of band 5 to band 4 was 50% greater in the drought months than in the periods following heavy rains. The September TM data also showed significant drought stress, and indicated that the trees remained in a stressed condition despite widespread rains in August.

Longleaf pine growth was measured for the period from 1983 through 1993 using tree ring cores collected in 1996. From 1983 through 1989, tree ring widths were positively correlated with annual precipitation and indicated the importance of precipitation in determining longleaf pine growth. During 1990, growth was significantly reduced with tree ring widths being 20 % narrower than those observed for preceding years of average rainfall. Furthermore, the degree of growth depression observed for a stand was correlated to the degree of drought stress indicated by the TM data. The greater the indicated drought stress, the greater the degree of growth depression. There was no significant growth depression in 1991, which was the wettest year in the last 50 years, but significant growth depression was observed for 1992 and 1993, which were years of average rainfall. The degree of growth depression in 1992 was correlated with the degree of drought stress indicated by the TM data for 1990. Ring widths for 1992 and 1993 were smaller than those for 1990, and indicated severe growth depression continuing for three years following the drought.

The continuation of growth reductions for three years following the drought illustrates the potential susceptibility of longleaf pine plantations to drought effects. It is likely that the effects of the 1990 drought would have been much greater if it were not for the unusually high precipitation in 1991. If 1991 had been another relatively dry year, there would have been even more growth depression and the possibility of increased mortality and susceptibility to disease and insect infestations. The result of the 1990 drought has been a reduction in longleaf growth and wood volume. If 1991 had been dry, the result may have been costly salvage and disease control operations.

Droughts are largely unpredictable events. Moreover, their intensities are often spatially

variable due to the occurrence of localized thunderstorms which may produce areas of reduced drought stress. The correlation of drought stress indicators from TM data with reductions in longleaf growth rate provides a readily-accessible, cost-effective method to assess the potential damage and plan for the projected impacts of drought on the extensive areas of SRS forests.

Carolina Bay Restoration

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

Most of the 10,000 to 20,000 Carolina bays in the southeastern U.S. Coastal Plain have been functionally altered through ditching, draining and/or other disturbances. Many of the nearly 300 bays on the SRS were drained by previous landowners and converted to agricultural use. These bays are no longer dominated by wetland species, and they do not sustain many natural wetland functions. Research by SREL, with cooperation from the Savannah River Forest Station (SRFS) seeks to develop cost-effective and successful methods to restore depressional wetlands, to develop and test indicators of ecosystem health or conditions, and to develop and test landscape assessment approaches for sustainable management. The SRS provides a unique opportunity to develop technologies to restore ecosystems such as Carolina bays, and to develop metrics of ecosystem conditions. Restoration of drained bays may be achieved more easily and for less cost than the restoration of more highly disturbed ecosystems. Furthermore, restored Carolina bays may serve to mitigate other wetland losses.

SREL, in cooperation with SRFS, has developed a research program to evaluate efficient methods for restoring Carolina bay wetlands and management practices that may enhance restoration. A four-hectare Carolina bay (Bay 93) supported herbaceous marsh vegetation in 1951, according to surveys of aerial photography. Drainage of the bay since that time has permitted invasion of upland species, including loblolly pine and sweetgum. In November 1993, the ditch in Bay 93 was plugged to restore the hydrology, approximately 50% of the timber was removed, and portions of the remaining forest burned. Julian Singer, a graduate student in the Botany Department, University of Georgia, examined vegetation in Bay 93 prior to application of these restoration treatments and for two years following blockage of the drainage ditch. In the first year, the bay was only shallowly filled with water, and the vegetation remained dominated by upland species. During the second year, the hydrology was more typical of undrained bays, and the vegetation was characterized by more wetland herbaceous species. The increased light and soil disturbance created by the removal of the forest vegetation and the burning stimulated germination of herbaceous species from the seed bank and accelerated recovery of the herbaceous marsh in these treatments. These results suggest that if wetland species remain in the seed bank of the disturbed wetland, vegetation recovery may be relatively quick once the hydrology has been restored.

During the last year, an interdisciplinary team has been organized to extend this initial research and to develop technology transfer activities for Carolina bay restoration. Participating

organizations in addition to SREL and the Forest Service are the Savannah River Technology Center, The University of Georgia, and University of South Carolina - Aiken. Restoration manipulations will be performed on a replicated set of bays, chosen by using the GIS data base and aerial photography, and site visitation. This research is expected to result in reduced costs and improved efficiencies for managing forest/industrial landscapes.

Swamp Forest Recovery Following Disturbance

Rebecca R. Sharitz and Diane DeSteven

Studies of the impacts to ecological systems of the industrial activities on the Savannah River Site (SRS), and the subsequent recovery of these systems, provide a valuable baseline for assessing the ability of natural ecosystems to withstand disturbance and the need for restoration and/or remediation. During the 40 year period of SRS nuclear reactor operations, cooling-system waters (30-60°C above ambient) were discharged into streams flowing into the floodplain of the Savannah River, destroying large areas of the original swamp forest. Since reactor shutdown, research on wetland restoration and on natural recovery of wetlands has been conducted to establish a framework for larger-scale restoration efforts. Projects in Fourmile Branch delta and Pen Branch delta have been conducted to assess the pattern and rate of natural swamp forest recovery.

In Fourmile Branch, data from permanent vegetation plots established in 1987 have been combined with analyses of color infrared aerial photographs from 1985, 1990, and 1993 to examine the rate and pattern of plant succession following shutdown of C-Reactor in 1985. Between 1985 and 1993, tree and shrub coverage in the 60-ha study area increased from 3 ha to 33.5 ha, and trees and shrubs now cover well over half of the extensively disturbed area. Woody species establishment was most rapid within 50 m of the surviving forest around the edge of the delta. Although vegetation recovery is proceeding steadily, the primary tree species are loblolly pine (*Pinus taeda*) and willow (*Salix spp.*), both early-successional trees that are wind-dispersed. There has been very limited recovery of the original hardwood and swamp forest canopy species.

In the downstream parts of the Pen Branch delta, where a few canopy forest trees survived the thermal disturbance, recovery is occurring more rapidly. Five years after the closure of K-Reactor in 1988, saplings of the major canopy species water tupelo (*Nyssa aquatica*) and baldcypress (*Taxodium distichum*) were abundant, along with willows and several species of shrubs. The extent of forest recovery is related to the availability of seeds and suitable conditions for germination and seedling establishment. The similarity in size-class distribution of the saplings suggests relatively synchronous recruitment, and basal growth-ring counts of selected saplings show that establishment occurred in 1985-1986, prior to reactor shutdown. Water level records from Pen Branch show that floods occurred during the growing season of 1984 and again in the early 1990's, but not during 1985-1989. Thus, the survival of a few canopy trees (which served as a seed sources) and the absence of growing season floods provided

an opportunity for natural regeneration of canopy species.

These studies of recovery of the extensively disturbed wetland forests provide a baseline for assessing the success and effectiveness of wetland forest restoration efforts in Pen Branch. This work also suggests that recovery depends greatly on the post-disturbance hydrologic condition (in this case timing and duration of floods), substrate conditions , and availability of propagules. When surviving trees provide at least some seed input, canopy species recovery proceeds more rapidly and artificial restoration is not needed.

Aquatic Communities of Natural Wetland Ponds

Barbara E. Taylor, Doug A. Leeper, and Adrienne E. DeBiase

The Carolina bays and other natural wetland ponds on the Savannah River Site support some of the richest aquatic communities in North America. During the past year, our research focused on analysis of additional data from a 12-year study of microcrustacean population dynamics in Rainbow Bay, completion of a two-year study of insect emergence at Rainbow Bay, description of a new calanoid copepod species, and completion of an analysis of biogeographic patterns of calanoid copepods. Continuing work concentrates on applications of a population dynamics model for the marbled salamander to problems in ecological risk assessment.

Rainbow Bay. Planktonic and benthic invertebrates are the main trophic link between primary producers and vertebrate consumers in Carolina bays and other wetland ponds. The 12-year study of Rainbow Bay is the only long-term data set to focus on wetland pond invertebrates in the southeastern United States. Two different studies, both utilizing a 12-yr record of data at Rainbow Bay, explored the adaptations of aquatic invertebrates to the hydrologic variability in Rainbow Bay. One study focused on the calanoid copepod *Aglaodiaptomus stagnalis*, the other on a suite of cyclopoid copepods.

Aglaodiaptomus stagnalis is the only calanoid copepod species in Rainbow Bay. Analysis of field data shows that the timing and duration of pond filling are the dominant influences on its population dynamics. Hatching from resting eggs occurs only if the pond fills in November-April. It produces only one generation annually, and this generation may be lost if the pond dries before it matures and reproduces. Although habitat duration is often assumed to be the primary factor regulating populations in temporary ponds, our demographic analyses indicate that biotic factors, including competition with other microcrustaceans and predation, also exert strong influences on the dynamics of *A. stagnalis*.

An analysis of field data for ten species of cyclopoid copepods, conventionally regarded as ubiquitous generalists, demonstrates that cyclopoids have a complicated array of strategies for breaking and entering dormancy, including early or late emergence, seasonally cued emergence, and single or multiple generations. Computer simulations suggest that some of these

strategies effectively exploit high variability in filling and drying times.

These results extend the databases available for considering biotic effects of management, particularly hydrologic alterations, on the aquatic communities of Carolina bays. Because models enable us to experiment with various demographic and life history traits, they can help us to extract useful generalities from these demographic case studies.

A two-year study of insect emergence in Rainbow Bay revealed 115 taxa of aquatic and semi-aquatic insects from 29 families, representing seven orders. The most diverse and abundant group was the Chironomidae (midges) with 59 species, including several not previously observed on South Carolina or the southeast. Biomass of emerging adult chironomids was approximately one-third of the larval production, indicating a strong energetic link between aquatic and terrestrial components of this wetland.

Graduate Student, Vicki L. Medland completed and successfully defended her dissertation on diapause strategies of cyclopoid copepods. A manuscript on insect emergence at Rainbow Bay has been accepted, with revisions, by the *Journal of the North American Benthos Society.*

New species. Our survey work found an unknown calanoid copepod species from the family Diaptomidae. This species was described and given the name *Aglaodiaptomus atomicus*, which recognizes the SRS, where it was first discovered. *Aglaodiaptomus atomicus* is one of the most common calanoid copepod species observed in Carolina bays and other wetland ponds on the SRS. It has not been collected from other wetland ponds on the coastal plain of South Carolina. The description of this species and a close congener will be published in the *Proceedings of the Biological Society of Washington* in late 1997.

Biogeography and surveys. Our surveys of Carolina bays and other wetland ponds, in combination with our long-term studies, have been invaluable for characterizing these habitats within the SRS. They have provided baseline data for additional studies, including Carolina bay restoration projects, fish studies, and paleoenvironmental investigations.

The biogeographical analysis of the survey data indicates that the SRS is an area of high diversity for many groups of microcrustaceans. The 16 calanoid copepod species observed on the Site are equal to the number that occur on the Eastern Canadian Shield, St. Lawrence Lowland, and Northern Appalachia combined. A total of 18 species have been recorded for the Coastal Plain of South Carolina. The high diversity on the SRS may be due, in part, to habitat protection provided by the SRS. Also, new habitats for the microcrustaceans (i.e., reservoirs) have been created on the Site. A manuscript on the biogeography of calanoid copepods of the southeastern Coastal Plain is in press in the Journal of Marine Research.

Population dynamics. A computer-based population model, developed in collaboration with the herpetology program, was used to test and strengthen our understanding of ecological

risk to natural populations of pond-breeding salamanders. We analyzed the effects of chronic and catastrophic mortality on population dynamics of the marbled salamander, *Ambystoma opacum*. The model indicates that terrestrial stages are more sensitive than aquatic stages. Catastrophic mortality, particularly in the terrestrial stages, can cause extinction even when a corresponding average value for chronic mortality permits persistence. Further applications of the model to problems in ecological risk assessment are planned.

A paper on the model appeared in *Herpetologica*. The results on chronic and catastrophic risk will be published in the proceedings of the Fourth Annual SREL Symposium on the Environment.

Environmental Histories (In collaboration with the Savannah River Archaeological Research Program)

Barbara E. Taylor and Mark J. Brooks

Investigations of the historic and prehistoric conditions of Carolina bays on the SRS are being used to characterize long-term environmental change on the SRS and to provide baseline information for management activities. Our studies have focused on Peat Bay, located on a terrace of the Savannah River, and Flamingo Bay, located in the upland.

In sediments of wetland ponds on the SRS, diatoms typically preserve better than other microfossils. Evelyn Gaiser, a graduate student at the University of Georgia, determined that composition of diatom assemblages in surficial sediments of modern ponds of the SRS correlate strongly with hydrologic conditions. Using data from the modern assemblages, she constructed a calibration model that can be used to infer hydrologic conditions from such assemblages. She applied it to fossil assemblages from both Peat Bay and Flamingo Bay. The diatom-based inferences about paleohydrologies, combined with stratigraphic data, radiocarbon dates, archaeological histories, and other lines of evidence, indicate major environmental changes in the ponds.

The diatoms of Peat Bay record a transition from a permanent pond with open water to a wetland pond about 4000 yr B.P. This transition probably coincides with the establishment of the modern floodplain of the Savannah River. The conditions in this wetland pond varied, with a conspicuously drier period occurring around 1500 yr B.P. Most recently, the diatoms record a sharp transition from a temporary pond to a permanent pond; this transition probably marks the onset of seepage from L-Lake, which was filled in 1985.

At Flamingo Bay, which is isolated from fluvial influences, the record suggests two significant transitions. The onset of modern conditions, including the inundation of an interior ridge, seems to have occurred in the early historic era, about 300 yr B.P. An earlier, but smaller expansion of the ponded area seems to have occurred about 3000 yr B.P., suggesting a shift to

a moister climate.

A paper on the geoarchaeology of Flamingo Bay was published in *Geoarchaeology*. Manuscripts on the modern diatom flora, the calibration model, and bay geomorphology have been accepted for publication.

DWPF Construction and an Experiment in Mitigation*

Joseph H. K. Pechmann, David E. Scott, and Ruth A. Estes

For 18 years (1978-1996) SREL's research examining construction impacts of the Defense Waste Processing Facility (DWPF) provided DOE with data for compliance with the National Environmental Policy Act, Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands), and DOE guidelines for compliance with Floodplain/Wetlands Environmental Review Requirements (10 CFR 1022). Before construction, the 243 ha DWPF site contained a Carolina bay and the headwaters of a stream. The primary focus of SREL's ecological studies has been to assess the impact of DWPF construction on biota associated with these wetlands, and the effectiveness of mitigation measures undertaken by DOE.

Despite the loss of direct funding for this project by DOE during FY '97, studies have continued during the past year in accordance with commitments outlined in the DWPF Environmental Impact Statement. SREL's studies were begun in late 1978, and DWPF construction commenced in late 1983. Because this project is recognized nationally and internationally among both the scientific community [see SREL publications in major journals (e.g., *Science, Bioscience, Ecology, American Naturalist*) and recent books] and in popular news media (e.g., *Smithsonian* magazine and *Audubon* magazine, CNN news, and *Atlanta Constitution*) SREL considered its continuation to be in the best long-term interest of both the University of Georgia and DOE. The DWPF facility became operational in FY-1996; the next four years will allow SREL to complete the post-construction phase of the study. Current research emphasizes: (1) monitoring the water quality of peripheral streams that were impacted by DWPF construction; (2) understanding the population dynamics of amphibian species so that human-induced changes can be separated from naturally occurring population fluctuations; and (3) studying the role of terrestrial buffer zones around wetlands in maintaining the viability of wetlands biota.

Water quality monitoring has been conducted monthly, with an emphasis on sampling after rainfall. Water samples were analyzed in the laboratory for turbidity, total suspended solids (TSS), specific conductance, and percent ash. SREL studies documented significant impacts of DWPF construction on water quality in the Upper Three Runs Creek watershed, although Upper Three Runs Creek itself remains unimpacted. Despite some recovery towards the end of the construction period, water quality parameters remained elevated in peripheral streams following high rainfall events during FY-1996, necessitating further monitoring.

When DWPF was built, an entire Carolina bay (Sun Bay) was eliminated. Carolina bays are important centers of biodiversity, especially for amphibians. Alternative breeding sites for amphibians were constructed adjacent to the construction site as an experiment in mitigating the loss of Sun Bay. Studies by SREL demonstrated that these "Refuge Ponds" provided partial mitigation of the loss of amphibian breeding habitat. Difficulty in duplicating the hydrological cycle of a Carolina bay was found to be one factor that limited the success of the mitigation. Changes in the amphibian community at the DWPF construction site and at the Refuge Ponds are being compared to those at a control site, Rainbow Bay. Data from Rainbow Bay have been relevant to separating natural population fluctuations from declines due to human activities around the world as well as on the SRS. Reports of widespread, unexplained declines and disappearances of amphibian populations over the last 20 years have led many to speculate that amphibians are indicators or biomarkers for serious unknown or underestimated impacts of human activities (e.g., ozone depletion). Data from the DWPF control site, Rainbow Bay, have figured prominently in scientific discussions of this issue. Recent analyses indicate that population sizes of four amphibian species have declined at Rainbow Bay over the last 18 years, whereas numbers of one species have increased. SREL research indicates that these changes most likely are natural fluctuations related to climatic variation, predation, competition, and other natural interacting factors. Data from Rainbow Bay represent the longest ongoing multispecies study of amphibian populations in the world. In spite of this, statistical power analyses developed during FY'96 indicate that additional data are needed to adequately assess long-term trends, due to the high natural variability in population sizes.

Census data from Rainbow Bay and results from experimental manipulations of larval salamanders at other sites were used to construct a simulation model that describes the effects of larval density dependence on the population dynamics of the marbled salamander. The model was sensitive to parameters that described the terrestrial stage of the life cycle of salamanders, and underscored the importance of additional data on the demography of the terrestrial stage. Future modeling efforts will incorporate environmental stochasticity (in addition to density-dependence) in order to provide a better understanding of population regulation, more realistic predictions of population dynamics, and a sound basis for management plans. These research projects are important for understanding the relationship between direct impacts of human activities on wetlands, such as the elimination of Sun Bay, and indirect effects such as the construction activities adjacent to Sun Bay.

***Funded by DOE-SR Defense Production**

C. Ecotoxicology, Remediation, and Risk Assessment

With DOE's need to clean up the accumulated contaminants from more than 40 years of operation information about the fate and effects of these contaminants and effective strategies for cleanup are needed. The ETRRA Group's activities focus on research, interfacing with SRS professionals and developing and conducting workshops and short courses that deal with ecotoxicology, remediation, and risk assessment.

ETRRA's research activities focus on:

- *Fate and effects studies of contaminants at all levels of ecological organization*
- *Evaluation of the effectiveness of plant-based remediation activities*
- *Studies of utility to SRS environmental professionals including risk assessors*
- *Generation of baseline data for ecotoxicological processes and baseline ecological data*
- *Generation of new methods for assessing impact, risk and recovery*

ETRRA will interface with SRS Professionals by:

- *Participating in environmental management meetings and activities as much as possible*
- *Pulling together SREL information for application to SRS environmental management.*

ETRRA will:

- *Develop workshops and short courses for training SRS personnel and to promote interactions between SRS professionals and experts*
- *Generate books and documents containing supporting knowledge for SRS and other DOE site activities in ecotoxicology, remediation and risk assessment*

Innovative Uses of Coal Combustion Residues

Domy C. Adriano, John Weber, and Anna Chlopecka-Knox

This program was initiated to investigate the release and biogeochemical cycling of contaminants in soils, surface and groundwater from coal piles and ash basins. Analysis results indicate runoff effluents from coal piles at the SRS, particularly in the D- Area, are contaminating the groundwaters below.

An off-shoot of this original program was established in 1994 on the Mason's Tree and Turf Farm in Beech Island, South Carolina. This project was to determine the effectiveness of fly ash (up to 10 Cm surface applied and incorporated into the soil) in enhancing the growth and performance of turf species in alluvial soils that may have some undesirable soil-plant-water relations. However, the success of this technique was contingent on sustaining desirable water quality underneath the treated area. Results indicate that no detrimental effects on the turf species were observed and that better soil-plant-water relations were obtained by increasing the water holding capacity of the soil and providing a better substrate for the roots.

A second study utilizing fly ash was begun at the Columbia Metropolitan Airport, in a seven ha borrow pit. This reclamation project was initiated to reduce sedimentation of a road from a nearby borrow pit. The eroding borrow pit is largely non-vegetated due to infertile soil conditions. The project was initiated as a multigroup activity between industry, the Soil Conservation Service, SREL, and South Carolina Division of Health and Environmental Concern (SC DHEC). This reclamation project consists of two parts: an experimental plot where treatments included various application rates of fly ash and chicken manure, either singly or in combination; and the rest of the area as a demonstration to indicate the potential significance of the fly ash as a soil quality enhancer. Plot treatments included fly ash rates of up to 10 Cm of surface material and chicken manure rates to provide 180 kg/ha of nitrogen. Massive applications of weathered fly ash have no adverse effects on plant growth (mixed culture of panic grass, lespideza, lovegrass), which are consistent with the results seen at Mason's Turf Farm. Chicken manure enhances plant growth substantially, apparently much better than inorganic commercial fertilizers. The results from the turf farm and the airport project should be beneficial to SC DHEC in regulating this waste by-product for agricultural lands and physically degraded areas.

A new project "Coal combustion flue gas desulfurization (FGD) waste -exploratory innovative use" was initiated this year. This preliminary greenhouse study is being conducted to (1) evaluate the effect of this material on physical and chemical properties of the soil, and the chemical leachate, (2) determine whether heavy application of FGD (10%) will create result in excessive metal and salts leaching, and deteriorating soil quality, (3) determine if there is a positive effect (e.g. improvement of soil physics, increase of nutrient, liming effect), and (4) collect background data for future mesocosm and field studies. The experiment has seven

treatments, which include FGD: 0%, 1%, 2%, 4%, 6%, 8%, and 10% FGD added to soil separately.

In situ Remediation Techniques for Contaminated Soils

Domy C. Adriano, Anna Chlopecka-Knox, John Weber, and Christopher J. Durden, (University of South Carolina, Aiken)

In-situ stabilization offers an attractive alternative to conventional remediation techniques by enhancing natural attenuation mechanisms that control contaminant migration, bioavailability, and toxicity. *In-situ* techniques reduce the potential for worker exposure during remediation; they are typically less expensive and disruptive to the natural landscape and hydrology than conventional excavation, treatment, and disposal of contaminated soils and aquifer sediments; and they generally require less long-term monitoring and management after implementation. *In-situ* stabilization includes: (1) enhanced chemical precipitation of toxic metals and radionuclides; (2) redox manipulation to promote reduction and subsequent immobilization of redox-sensitive contaminants (e.g., Cr and U); and (3) in-situ reactive chemical barriers. This program was created by redirecting funds from the old Biobarrier Program and, more recently, from the cycling of Coal/Fossil Fuel Contaminants Program. The Contaminant/Remediation Program has two components: (1) radionuclides as the contaminant and (2) metals as the contaminant. In the fall of 1992 garden plots were established at Par Pond to examine radionuclides in lake sediments. This study was precipitated by an earlier dose assessment which indicated that a hypothetical lake basin inhabitant, that ingested food products, in this area would be exposed to greatest risk. The study was initiated to evaluate remediation options for contaminated sediments that enhance food quality by minimizing radionuclide uptake by plants. Results indicate that clean soil cover over contaminated sediments resulted in lower cesium uptake than without clean soil. Other soil cover treatments (i.e., those with geo-textile fabric and a root biobarrier sandwiched between the clean soil cover and the contaminated sediments) resulted in even lower cesium uptake. All treatments involving soil cover produced concentration ratios at or below the National Council on Radiological Protection guideline value of 0.12. Other techniques tested (i.e., high K fertilizer application and zeolite (clinoptilolite) addition), resulted in some diminution of cesium uptake, but they were not as effective as the clean soil cover techniques. Over the project duration, soil cesium decreased with time and with soil depth, presumably due to the leaching of this element and some removal by crop biomass. The decrease with time coincided with uptake diminution with time, i.e., uptake was more pronounced in the first year than in the second year. The degree of cesium uptake was influenced by crop species and differed among plant parts. Deep-rooted collards accumulated more cesium than other species, and foliage of turnips, kohlrabi, radish, corn, and okra, accumulated more cesium than edible portions. The results from this study are being prepared for publication, and could be extrapolated to the remediation of severely contaminated soils, such as those affected by the Chernobyl reactor explosion in 1986.

An *in situ* remediation study of metal contaminated soil includes three greenhouse pot experiments. The first experimental study was started in the spring of 1994. Soil was spiked with metal flue dust from a scrap metal recycling facility. This material was very high in zinc, lead, and cadmium. After incubating the spiked soils, the following soil ameliorants were added: agricultural lime, hydroxyapatite, zeolite (clinoptilolite), and iron oxide from an industrial waste product called Fe-rich™. Crops (corn, radish, and barley) were used as treatment indicators of the various ameliorants. The use of lime appears to be as effective as the other materials in mitigating metal uptake, and because lime is fairly abundant and much cheaper than the other materials, it may be the ameliorant of choice. Results were published in *Environmental Science and Technology (1996, vol. 30, p. 3294-3303);* other results are in press in *The Science of the Total Environment.*

In winter of 1995 the study was expanded to investigate additional ameliorants on soils singly contaminated by heavy metals. In this second experiment, metals were added to the soil as a defined mixture of various metal sources (40% sulfate, 25% carbonate, 20% oxide, and 15% chloride). Metal levels (in mg/kg) were: As (200); Cd (20, 40); Cu (500, 1000); Ni (350, 700); Pb (1500, 3000); Zn (1000, 2000). After the soils were equilibrated for 4 weeks, one of the following amendments was added: lime, apatite, natural zeolite (phillipsite), Fe-rich ™ (a commercially available synthetic Fe oxide), and N-viro (an alkaline sewage sludge). Lime was added to adjust the soil pH to a value of 6.5 or 7.5; other amendments were added to the soil at rate of 25 g kg . Levels of Cu, Ni, and Zn were very toxic to plants; in treatments without amendments plants were killed in an early stage or yield was very small. All amendments decreased toxicity of these metals, and plant yield significantly increased in ameliorated treatments as well as significantly decreased metal mobility and plant uptake. Fe-rich ™, N-viro, and apatite appear to be the most effective ameliorant, based on plant yield , metal content of plant tissues, and bioavailable forms of these metals in soil. On a short basis, all amendments showed potential to reduce the mobile (i.e., exchangeable) fraction, but main "stabilizing" components of the amendments are reflected in non-available forms of these metals (e.g., carbonate, Fe-Mn oxide, organic or residual). Additionally, extract analysis and geochemical speciation indicate stable complex formation (e.g., Pb -apatite), complementing the sequential fractionation. Results of this experiment are published in *Plant nutrition for Sustainable Food Production and Environment.* T. Ando et al. (Eds.), 1997, 33-35, Kluwer Academic Publisher, Printed in Japan.

The third was established in early 1996 to study the economic rate of application for zeolite(phillipsite) and apatite for remediation of heavily polluted soils. Surface soils polluted by As, Cd, Pb, and Zn were taken from four countries (Canada, Czech Republic, Poland and Taiwan). Source of pollutant in these soils were mostly lead-zinc smelters. Addition of apatite and zeolite reduced uptake of Cd, Pb, and Zn by tested plants. Two levels of apatite and zeolite (25 and 50 g/kg) significantly reduced the amount of all metals in plant tissues; however, highest reduction was obtained with 50 g/kg Both doses of apatite and zeolite decreased the exchangeable form of Pb, Zn, and Cd. For example, 50 g of apatite per 1 kg of Czech soil decreased the exchangeable form of metals in order: Pb (61%) > Cd (55%) > Zn (46%). Data

from this study were published as an extended abstract in *Proceeding of Extended Abstracts from The Fourth International Conference on the Biogeochemistry of Trace Elements*, I. K. Iskandar et al. (Eds.), 23-26 June 1997, Berkeley, California, USA.

SREL Wood Stork Program: Foraging and Breeding Ecology

A. Larry Bryan, Jr.

Aerial surveys of the Savannah River Swamp System (SRSS), Par Pond and L-Lake reservoirs for Wood Storks were conducted from August 1 through October 10 of 1996, and April 10 through July 31 of 1997. During the Fall surveys (1996), storks were observed in the Steel Creek delta and Fourmile Creek delta of the SRSS during a single survey (each). During the spring and summer surveys (1997), storks were observed throughout the SRSS area. More than 25 storks were observed in several Carolina bays (Peat, Big Robbins and Steel Creek Bays, and Craig's Pond) and other temporally-isolated wetlands on the SRS. The increased use of the SRS during the spring is probably linked to the poor breeding season of the southeastern populations in the spring of 1997 as a result of a cool, yet dry, late fall and winter. This likely reduced prey and resulted in an abundance of non-breeding birds and/or failed nesting birds dispersing out from their respective colonies and using the larger bays on the SRS as foraging habitat.

Stork prey samples collected from several active (Carolina bays) and potential (reservoirs) foraging sites in 1996 were analyzed for the presence of mercury. Prey-sized fish, from the reservoirs, frequently contained levels of mercury above the level of concern as suggested by U.S. Fish and Wildlife Service (USFWS) for the diet of a sensitive avian species. However, many prey-sized fish from Carolina bays on the SRS also contained mercury at these same levels. Systematic samples of three fish species were collected from Carolina bays on the SRS in the summer of 1997 to address variation in mercury concentrations with differing hydrologies and water chemistry (pH, DOC). These samples will be analyzed for mercury concentrations in the fall of 1997.

The breeding success of storks in the Birdsville and Chew Mill Pond colonies in Jenkins County, Georgia, are being monitored, since they are the closest (approximately 45 - 50 km) sources of storks that might forage on the SRS and the Kathwood foraging ponds. There were 178 stork nests in Birdsville this year, which produced an average of 1.5 ± 0.84 fledged young per nest. The number of nests is similar to nest numbers from last year (185 in 1996), but lower than earlier years (245 in 1995). The Chew Mill Pond colony, which first formed in 1993, contained 84 stork nests which produced 1.2 ± 1.0 fledged young per nest. This colony, which is thought to be a satellite colony of Birdsville, was similar in size to the total nest count (98) from 1996. A colony discovered in 1995 in Screven County, Georgia (38 km SE of the SRS), reformed in 1997 with approximately 20 nests. This is half the number of total stork nests counted in 1996. We have not been able to secure landowner permission to enter this property

and, therefore, were not able to monitor reproductive success at this site. The poor-fair reproductive success reported here is primarily the result of the unfavorable weather patterns mentioned previously.

The Kathwood Lake foraging ponds were made available to the storks on July 3, 1997 when pond 4 was lowered. Storks have utilized the pond for approximately 3 weeks, with a single day maximum of 106 storks observed in pond 4. Studies of the foraging interactions between Wood Storks and Great Egrets continues. These two wading birds possibly compete for similar prey at Kathwood and other sites. Foraging behavior studies like this will assist in our determination of consumption rates of prey by these species. Unlike most previous years, the majority of storks using the ponds in 1997 were either adults or sub-adults (1-3 yrs of age) instead of juveniles (hatched in 1997). This difference is most likely the result of the poor-fair reproductive success in the local colonies, as well as throughout the states of Georgia and Florida.

The SREL Wood Stork Program, in cooperation with Georgia Department of Natural Resources (GDNR), received funding from the U.S. Fish and Wildlife Service (Section 6) to study the foraging ecology of wood storks breeding in the Georgia coastal zone. Data analyses are on-going. Our program has also received additional USFWS funds from the GDNR to analyze blood and feather samples from stork nestlings throughout Georgia for mercury to determine if that metal is a potential threat to their survival.

Impacts of Water Level and Chemistry Changes in SRS Reservoirs: Cycling and Accumulation of Mercury and Trace Metals

Charles H. Jagoe

Trace metals such as mercury are pollutants of concern on the SRS. Mercury in aquatic systems can bioaccumulate in fish, and may result in health risks to humans that consume contaminated fish and ecological risks to pisciverous wildlife. This research examines trace metal bioavailability and bioaccumulation in aquatic systems as influenced by factors such as major fluctuations in water level or water chemistry. While much of this work to date has focused on impacts of Par Pond drawdown and refill on mercury cycling, we have studied mercury in other biota and other systems both for comparative purposes, and to anticipate future areas of concern.

Almost all the mercury accumulated by fish and by organisms that consume fish is in organic form (methyl mercury). Inorganic mercury entering a system via precipitation, surface or groundwater input must be converted to methyl mercury to be taken up by organisms in significant amounts. Mercury methylation is related to bacterial activity in sediments, and is enhanced at low pH and with elevated concentrations of dissolved organic matter. Mercury may also be transported in waters and watersheds when complexed to humic materials. The Par Pond

drawdown altered water chemistry and increased sediment resuspension. Terrestrial vegetation also became established on exposed mud flats when the water level was low. When Par Pond was refilled, this vegetation was submerged and began to decay. This process probably increased both bacterial activity and the release of dissolved organic matter, which in turn increased mercury methylation and mobility.

The database on mercury in the Par Pond ecosystem has been collected since 1991 and includes water samples collected at semi-monthly intervals, and samples of other biota from the pond, including forage fish, plants, benthic invertebrates, and alligators collected at irregular intervals. Largemouth bass samples have been collected at quarterly intervals from Par Pond beginning in December 1991, except for a period in 1992 when access to Par Pond was restricted. From fall 1991 through the end of 1995, mercury content of largemouth bass from Par Pond ranged from 0.05 to 3.80 mg Hg/kg wet mass. Mercury content did not differ among sampling locations within Par Pond, but was strongly related to fish size; larger fish had higher mercury concentrations. Bass condition factor initially increased after the drawdown, due to the greater availability of prey displaced from shallow, weedy areas by the lowered water level. As the prey populations declined from increased predation, condition factor began to decline. About six months after the drawdown, there was a transient increase in muscle mercury concentration in bass, possibly related to changes in diet. However, through the drawdown period until refill began, there was no significant overall trend in bass mercury content. Mercury concentrations in 300-400 mm size bass averaged about 0.5 mg Hg/kg wet mass from fall 1992 through winter 1995, when Par was refilled. By the summer of 1995, average mercury concentrations in muscle in these size bass had increased to about 1.0 mg Hg/kg wet mass, presumably reflecting enhanced methylation and bioavailability following refill.

Bass tend to average out short-term fluctuations in mercury availability because they are relatively large, long-lived fish. To detect shorter term effects, we collected samples of several small, shorter lived fish species before and after the refill. Analysis of samples collected before refill showed that forage species varied considerably in mercury content, and were highest in brook silversides (mean 0.13 mg Hg/kg wet mass). Mercury concentration also increased in three forage species following refill.

Mercury concentrations typically increase with higher trophic levels, and long lived, top-level predators, such as alligators, can accumulate substantial concentrations. In samples from 50 Par Pond alligators, mercury averaged 17 mg Hg/kg dry mass in liver and 2.2 ppm in whole blood. Juvenile alligators samples from a Hg contaminated area in the Everglades contained much more mercury in their internal organs than larger Par Pond alligators, although muscle mercury concentrations were similar. Alligator samples for comparison purposes were also obtained from central Florida and the Okefenokee swamp in south Georgia. Changes in alligator mercury concentrations in Par Pond after refill were not detected. This may be related to small sample sizes, or the short time between refill and sampling. We are continuing to sample alligator tissues to detect longer-term trends and are attempting to correlate mercury levels in internal organs with readily sampled tissues such as blood and scutes. This would allow

non-lethal, repeated sampling of individuals, and would be useful for biomonitoring. Results suggest, that while Hg levels in these tissues are related to concentrations in internal tissues, the variability is too high to allow accurate predictions on an individual basis. However, sampling these readily obtainable tissues may be useful for population-level screening.

Studies of trace metals in other SRS waters continue. Yellow bullheads from Pond B collected in 1990 and 1994 were analyzed for muscle Hg and ^{137}Cs, and a subsampled for other trace elements. Radiocesium body burdens reached asymptote at about age three, and did not increase further with fish age. In contrast, mercury concentrations continued to increase over the life of the fish. Fish age was a much better predictor of mercury content than fish size. Three year old bullheads from Pond B contained about 4500 bq ^{137}Cs/kg wet mass, and about 0.5 mg Hg/kg wet mass. Concentrations of the other trace metals (Cd, Cu, Pb, Zn) were very low and not related to size or age. One manuscript detailing these findings has been published and another is in preparation.

In anticipation of the shutdown of the river water pumping system bass and forage fish species from L-Lake are being sampled. L-Lake bass contain mercury, but present levels are lower than similar sized bass in Par Pond. Comparison with older data suggests a possible decrease in mercury concentrations over time. This may be related to initial enhancement of methylation and transport when the reservoir was constructed, with subsequent decline and stabilization over time. Similar trends have been reported following construction of hydroelectric reservoirs in northern boreal areas.

To address potential concerns about risks to wading birds using mercury-contaminated areas in the event of a drawdown of L-Lake, studies have been initiated to document mercury in juvenile wood storks and their diets. In a study of food items collected at four stork nesting colonies in Georgia, freshwater fish generally contained higher mercury concentrations than estuarine or saltwater prey items. Colonies foraging exclusively in freshwater areas were at greater risk from dietary mercury exposure than those foraging in coastal areas. Drawdown of SRS reservoirs might create transient shallows and wetlands, and thus expose foraging storks to elevated mercury levels.

An initial survey of several Carolina bays in the summer of 1996 showed detectable mercury in all fish sampled, and most benthic invertebrates. These locations did not receive mercury contaminated water from the Savannah River and, it is likely that these systems are receiving mercury from atmospheric deposition, as widely documented in other regions. Fish from bays along a transect on the SRS were systematically sampled to further document this phenomenon, and await analysis. Elevated mercury concentrations in fish from such sites would strongly suggest atmospheric transport of mercury from offsite locations, than from SRS operations. Studies of mercury burdens in amphibians and reptiles that feed in these sites have been initiated as a first step toward estimating ecological risk. Sampling of bays and other wetland locations will continue to monitor Hg levels and to assess potential impacts.

Sampling of fish and other biota will continue in 1997. To better understand mercury cycling in SRS waters, speciation methods are being developed based on isothermal gas chromatography with atomic fluorescence detection. This will allow direct measurement of organic and inorganic mercury forms, and improve our understanding of the factors influencing transformations among these forms that bioaccumulate.

Mercury in Par Pond Sediments: Body Burdens and Sub-lethal Impacts in Mosquitofish

Margaret Mulvey and Michael C. Newman

Bioaccumulation and potential impacts of mercury associated with Par Pond sediments is being assessed in experimental mesocosms with mosquitofish, *Gambusia holbrooki*, as the indicator species. Eight mesocosms have been established to evaluate potential long-term, sub-lethal effects. Mercury accumulation in mosquitofish has been determined for fish maintained with Par Pond sediments and experimentally elevated mercury, as well as controls (no added mercury). Allozyme genotype frequencies have been determined for mosquitofish used to initiate the mesocosm populations. Mosquitofish have been harvested following approximately six generations in the experimental conditions. Allozyme frequencies are being assessed to evaluate potential genetic responses associated with the mesocosm conditions. We have evaluated the feasibility of using variation in the DNA sequence of the Internal Transcribed Spacer-1 region of the ribosomal array of mosquitofish to assess possible genotoxic impacts on the fish. Preliminary data indicate that the ITS-1 regions is variable. However, intra-individual variation in this highly repetitive DNA sequence may limit its applicability as an indicator of toxicant stress. This research will provide as assessment of potential changes in tissue concentrations of mercury and impacts on an indicator species that can be used to make decisions regarding remediation efforts for mercury-contaminated sites on the SRS.

Ecotoxicological Research

Michael C. Newman

This program evolved from a more narrowly focused effort on metal ecotoxicology. It contains three components: ecotoxicological research, quantitative methods development, and outreach/training. The ecotoxicological research explores bioaccumulation and effects of SRS-related toxicants. In the second component, quantitative methods that will facilitate activities associated with ecological risk assessment (ERA) are identified, evaluated, developed into convenient reports and software, and disseminated. The third outreach/training component provides short courses, workshops, professional expertise, and written materials in support of SRS ERA activities.

Ecotoxicology Research. Bioaccumulation studies of SRS-related pollutants have been completed for two fish species common on the SRS, the channel catfish (*Ictalurus punctatus*) and largemouth bass (*Micropterus salmoides*). Clearance volume-based pharmacokinetic models for ^{137}Cs, Cd, Hg, Pb, and Zn in catfish have been fit and manuscripts were submitted that describe the results. These models will enhance our efforts to assess accumulation of these metals in an SRS-pertinent species. Similar studies of methylmercury pharmacokinetics in catfish and bass have also been completed and data are being fit to candidate models.

Sediment avoidance assays were published for clams and snails exposed to Tim's Branch and D-Area ash basin sediments. Models based on the results suggested that measured sediment avoidance for these mollusks was too slow to allow effective movement from contaminated to clean sediments.

Studies with biochemical indicators of population-level response in mosquitofish to toxicants were extended to sublethal, chronic exposures. Use of glucose phosphate isomerase (PGI-2) as a marker of sublethal, population effect was described in a recently published manuscript.

The Microtox® assay indicated no toxicity associated with Tim's Branch waters and some toxicity associated with Steed's Pond sediments. QSAR-like models have been developed to describe relative toxic metal effects and interactions for this assay. Studies incorporating other SRS-related toxicants in the models continue. Also, models have been successfully extended to rapid assessment assays based on soil nematode mortality.

Quantitative Methods. Ecological Risk Assessment related quantitative methods were developed during FY '95. Version 4.0 of a software package (UNCENSOR) allowing univariate estimation for chemical data sets with "below detection limit" observations was released to 400 registered users. Extensive simulations comparing the incorporated methods have begun. A manuscript describing bootstrap methods of estimating community-level NOEAC has been accepted for publication. The book *Quantitative Methods in Aquatic Ecotoxicology*, by M. C. Newman, described and compared ERA-associated methods.

Education/Training. A short course, *Quantitative Methods in Ecotoxicology*, was first taught in FY 95 and again in August 1996. A book. *Ecotoxicology: A Hierarchical Treatment* describing the results of the Second Savannah River Symposium was published. A workshop, *Quantitative Risk Assessment*, was held in August 1996 and chapters are being compiled into a book.

Ecological Effects of the Proposed SRS River Water Shutdown: Wildlife Studies

I. Lehr Brisbin, Jr.

This program was initiated to study SRS wildlife populations which were impacted by the 1991 partial drawdown of the Par Pond reservoir. The work now extends to all site wildlife which are potentially affected by the proposed River Water Shutdown (RWS) action. The program provides an ecological context to other SREL studies of contaminant fate and effects. The present program documents the natural history, general ecology, movement and behavior of those wildlife species which are of special concern because of their potential to act as vectors of radionuclides, heavy metals, or other site-generated contaminants to the foodchain of the hunting public. Of particular concern are the abundant populations of winter migratory waterfowl, resident breeding populations of wood ducks and upland game birds such as mourning doves, which may enter the SRS site, feed in contaminated habits, and then rapidly move offsite where they can be legally harvested by hunters.

While some data are collected from opportunistic observations of wildlife during the course of other studies (e.g., radionuclide uptake determinations), particular efforts have been made to place radiotransmitters on a number of adult alligators which have been resident in the Par Pond reservoirs throughout the period of drawdown and subsequent refill. Using these radiotransmitters to periodically relocate adult breeding females has allowed the determination of reproductive effort (e.g., clutch sizes, hatching success, etc.) in these alligators throughout the reservoir drawdown and refill processes. Molecular genetic studies of the alligators are also underway.

Systematic boat cruises are made seasonally around the perimeters of Par Pond, L-Lake, and Pond B to census and evaluate spatial and temporal changes in the resident bird community structure and diversity of these reservoirs. These boat cruises provide a verification for companion aerial surveys for wood storks, waterfowl, and bald eagles which are conducted by SREL.

Studies of wood ducks using nest boxes in the Par Pond reservoir system have emphasized the uptake of mercury and were undertaken in cooperation with the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) of Rutgers University. As a result of funding limitations, however, most all of these long-term studies of wood ducks have been discontinued until new sources can be obtained.

Screech owls which showed leg abnormalities when discovered in a Par Pond nest box in 1995 remain at the Patuxent Environmental Science Center of the National Biological Service, where they have been paired and bred with normal captive owls. These breedings produced offspring with similar leg abnormalities similar to the original owls.

Future work in this program will emphasize studies of the wildlife resident on and around L-Lake in an effort to determine the basic ecological characteristics of these populations and predict their responses to habitat loss with the shutdown of the river water system at the SRS.

Cobalt Tolerance of Two *Nyssa* Species

Kenneth W. McLeod and Thomas G. Ciravolo

Portions of the forest canopy below the F-Area Chemical Separations Facility on the Savannah River Site were killed along a seepline paralleling Fourmile Branch. The water emerging in the seepline has been contaminated by long-term leakage from seepage basins which received liquid waste effluents from F-Area. Causative factors of the forest die-off are difficult to determine due to the large number of chemicals in unusual concentrations outcropping in this seep. In spite of the excellent efforts of the SRS in closing the seepage basins and installing pump-and-treat systems in the area, the migration of the contaminants will likely continue for some time since the contaminants have been present in the groundwater for several decades and will continue to emerge in the seepline.

In and surrounding the areas where the forest canopy has been killed, the vegetation appears fairly healthy, but varies according to species. In August of 1996, 10 species, mostly woody, were sampled to examine for unusual elemental concentrations in the leaves. One species, swamp tupelo *(Nyssa sylvatica var. biflora)*, had high leaf concentrations of cobalt (155 ppm) and nickel (27 ppm). Literature indicates that high leaf Co concentrations in *Nyssa* species have been observed when high Co concentrations occur in soils and sediments. These species readily absorb Co and can tolerate high concentrations of Co in the leaf tissue before excess Co symptoms occur. This characteristic of the *Nyssa* species could potentially be used to revegetate Co contaminated areas or phytoremediate Co-contaminated soils.

Greenhouse experiments are currently being conducted to determine if water tupelo (*N. aquatica)* and swamp tupelo *(N. sylvatica var. biflora)* could be used to effectively remove Co from Co-enriched environments. The tolerance of Nyssa species to Co and their ability to thrive in saturated soils make these species especially interesting for revegetating contaminated wetland sites.

Contaminant Dynamics in Reservoirs

Barbara E. Taylor

Accidental releases of radioactive contaminants are among the potential costs of nuclear technology. Decisions about remediation plans for these contaminants depend on reliable assessments of their environmental mobility. The experience and data from the Savannah River

Site can be used to test and improve our understanding of the fate of radionuclides in lakes and reservoirs, both on the SRS and elsewhere.

Existing published and unpublished data have been analyzed to identify areas of uncertainty concerning the inventory of ^{137}Cs in Pond B. In 1963-1964, radioactive material was accidentally released from R-Reactor. The most abundant long-lived radionuclides in the release was ^{137}Cs, and much of the contamination was transported into Pond B, an 87 ha reservoir. For the Pond B ecosystem, the effective half-life of ^{137}Cs appears to be shorter than its 30 yr radiological half-life. Assuming that the rate of export is proportional to the inventory, 2% of the ^{137}Cs inventory in Pond B is lost annually to radioactive decay within that system and about 5% of the inventory must be exported. However, the best available estimates of annual export are two orders of magnitude smaller than the estimate obtained from the difference between the radiological half-life of ^{137}Cs and its effective half-life in Pond B. Thus, given the current information, the ^{137}Cs budget for Pond B seems not to balance. Similar discrepancies occur in other rates and processes inferred from the inventory data.

Whether these imbalances are artifacts of statistical error or symptoms of conceptual error is unclear. We are currently applying uncertainty analyses to a mass balance model for radiocesium in Pond B.

D. Radioecology

Four decades of cold war production and distribution of radionuclides have resulted in releases of radiation into many ecosystems in the United States and Eurasia. The impetus for greater detailed information on kinetic processes, fate and effects on biology, and the relationship between absorbed dose and individual, population and community responses is provided by review of DOE by the National Academy of Sciences, by evaluation of revived missions and strategic plans for the DOE at the Savannah River Site and elsewhere, and by various state and federal agencies. The study of radiation in the environment has been a central tenet for SREL researchers. At one time the Savannah River Ecology Laboratory was named the Institute for Environmental Radiation. At this time, SREL remains as one of very few academic institutions deeply committed to the discipline of radioecology.

New 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 to nonhumans from mixed wastes*
- *Dose assessments for plants and animals exposed to environmental radiation*
- *Genetic changes in response to previous plant operations*
- *Assessment of environmental problems associated with radionuclidos in the environment*
- *Development of bioindicators as a cost effective way for assessing risks*
- *International programs in radioocology.*

Radionuclide Cycling in Vertebrate Wildlife Inhabiting Contaminated Habitats on the Savannah River Site

I. Lehr Brisbin, Jr.

This program initially focused on the development of an inventory of radionuclide contaminants (particularly the gamma-emitting isotope ^{137}Cs) in both the abiotic and biotic components of the Pond B reservoir on the SRS. More recently, the emphasis of this program shifted to a general study of the fate and effects of radionuclide contaminants and their synergisms with other site contaminants such as heavy metals, particularly mercury, in a variety of wildlife species residing in aquatic and terrestrial habitats on the SRS.

This work continues to document levels of contaminants in free-living wildlife, particularly those such as fish, deer, upland game birds, and migratory waterfowl which might move off the SRS and be legally harvested and consumed by the public. Wildlife are collected by shooting, trapping, or netting, and whole-body radionuclide burdens are determined on sacrificed individuals. In some organisms, gamma-emitting radionuclides can be quantified without harm to the individual and these animals can then be released for later recapture and subsequent changes in contamination levels. Miniature radiotransmitters are attached to selected organisms to assist in their multiple recaptures, permitting the production of a time-series data set describing contaminant uptake or elimination under free-living natural conditions. Frequent use is also made of surrogate sentinel species such as game-farm mallard ducks or free-ranging feral bantam chickens. These sentinel animals can be tamed and imprinted, facilitating their later capture and return to the laboratory for further contaminant body burden analyses.

With the completion of the refill of the Par Pond reservoir, studies were undertaken to evaluate long-term changes in ^{137}Cs contamination levels of waterfowl using this site before, during and after reservoir drawdown. An unexpectedly high increase in contamination levels of this isotope in American coots prompted more detailed studies of the behavior and dietary habits of these birds during and after the drawdown period. A study has now been completed and submitted for publication showing that ^{137}Cs declines in Par Pond coots prior to the drawdown occurred at rates approximating the rate of physical decay of the isotope. This study also showed that ^{137}Cs levels in coots did not decline at equal rates in all of the arms of the reservoir.

Several major studies have been completed and three manuscripts submitted for publication describing for mourning doves: (1) ^{137}Cs levels, (2) mercury levels, and (3) risk to hunters, for birds using the exposed Par Pond mudflats during the period of drawdown.

Analyses of the long-term ^{137}Cs database for over 30,000 white-tailed deer taken by hunters during the annual SRS fall hunts continue, and results, including spatial assessments (through GIS analysis) of deer ^{137}Cs contamination patterns, are now being prepared for publication. Radiocesium and mercury contamination levels have also been determined in

raccoons, foxes, and feral dogs using the SRS site. Studies of contamination levels in these species will be related to the same GIS spatial data base which is being developed for the deer ^{137}Cs studies.

In the future, as in the past and present, the same basic principles of experimental design and analysis will be maintained in order to provide a continuum of information through the history of management of these contaminated habitats on the SRS. Future studies in this area might also soon begin to focus on the semi-aquatic wetland marsh and swamp systems of the Steel Creek delta below the L-Lake dam. This habitat will almost certainly become a focus for management concerns and contaminant transport evaluation if any decision should be made to drain or otherwise alter the water level and flow regime in L-Lake.

Genotoxicology Studies

Ronald K. Chesser, Charles H. Jagoe, Michael H. Smith, and I. Lehr Brisbin, Jr.

This research seeks to further our understanding of the biological consequences of long-term exposure to pollutants that damage or otherwise affect genetic material, including radionuclides, heavy metals and other substances. The objectives include development of biomarkers of exposure and effect, determination of dose-response relationships, testing these responses in laboratory and field settings, and applying the results to judge health and ecological risks in polluted areas. To date, much of our efforts have focused on the development of methods to detect genetic damage and changes associated with contaminant exposure. Methods employed in this research include laser-based flow cytometry, DNA (alkaline) unwinding, electron microscopy, sequencing of nuclear and mitochondrial DNA, single-cell electrophoresis, starch gel electrophoresis, and standard karyology. The primary areas addressed in our studies are the Savannah River Site and associated bodies of water and the regions surrounding Chernobyl, Ukraine.

A paper detailing a large survey of possible genetic abnormalities associated with contaminant exposure is currently in press. In this study, we sampled blood from hundreds of largemouth bass from sites in the southeastern US with and without documented histories of contamination, including waters on the SRS, and analyzed them for DNA content by flow cytometry. We detected relatively few aneuploid individuals. However, we observed greater frequencies of fish with higher variation in DNA content of blood cells in some polluted locations.

Method development in the past year has included consideration of sources of variation in the single-cell electrophoresis technique. Understanding such variation is critical to detecting actual DNA damage associated with contaminant exposure, as opposed to variation associated with sample preparation and handling, and natural differences among and within organisms. We had previously performed similar quality assurance experiments to verify our flow cytometry

results. Radiation and some other environmental agents cause the formation of highly reactive chemical species (radicals) in tissues. Experiments to test methods to measure induction of defense mechanism against such radicals, including superoxide dismutase and glutathione were also performed.

We are expanding our analysis of the interaction of contaminants in complex mixtures by focusing on a the D-area coal ash basins. Small mammals collected from this area show a complex pattern of genotypic and phenotypic responses that are in part a response to the complex mixture of contaminants they are exposed to on a daily basis. This work also provides a cautionary note regarding reference sites. Reference sites only exist in reference to a specific toxicant and not to a broader scale clean versus contaminated dichotomy.

High rates of DNA strand breakage were found in catfish from the cooling pond adjacent to Chernobyl Reactor Number 4. Comparison of the number of strand breaks in these fish to those from uncontaminated regions in southern Ukraine indicate that catfish from the cooling pond are experiencing significantly higher rates of genetic damage. The primary pollutants in the cooling pond at this time are cesium-137 and strontium-90. Similar results were found for snails from contaminated bodies of water near the reactor at Chernobyl and for small mammals living in fields adjacent to the reactor when compared to those collected from rodents living in other areas.

Analyses of soil samples collected at Chernobyl in 1992 and 1993 have been completed; one manuscript is in press and another submitted based on the samples collected in 1992, and two manuscripts have been submitted describing the 1993 findings. Little radioactive contamination was found in regions to the south and east of the power plant in 1992, although lead levels in many of the fish sampled in this region were high. In contrast, fish samples collected from the north and northwest of the plant in 1993 had elevated radiocesium concentrations but were relatively low in mercury and lead. The latter observation suggests that the lead dropped into the burning reactor after the accident as a firefighting response was not vaporized and released into the local environment, as had been feared.

Another manuscript has been submitted describing the radionuclide concentrations in small mammals from the Chernobyl area, along with estimates of the relative importance of internal versus external radiation dose. Our results suggest that the external dose is higher than that received from ingested or inhaled gamma emitters. Other manuscripts are in preparation reporting levels of contamination in soils and in the muscle tissue of animals surrounding Chernobyl's Reactor.

Current research in this program includes assessment of genetic damage for the protein produced by the p53 gene. We are sequencing the p53 gene in rodents from the Chernobyl region, and have begun development of probes for use in fishes. The p53 gene is a tumor suppressor. When DNA is damaged, the p53 gene is activated producing a protein that blocks cell division until the DNA damage is repaired. Thus, this gene prevents the proliferation of

cells with damaged DNA which may lead to cancer. There is considerable current research into any mutations to the p53 gene that may adversely influence its tumor suppression function, and we are interested in the potential for measurement of such mutations as a tool in environmental genotoxicology. We have recently submitted a proposal (DOE EMSP) to develop a technique to assess DNA variants in p53, the D-loop and microsatellite DNA in freshwater turtles as a useful genotoxic biomarker for the monitoring of anthropogenic effects.

Distribution and Dynamics Of Radionuclides In Aquatic Ecosystems

Thomas G. Hinton and F. Ward Whicker (Colorado State University)

This research quantifies the concentrations of radionuclides in components of contaminated ecosystems on the SRS, and seeks to understand the basic processes that control the long-term dynamics of these contaminants. This research also provides site-specific data for DOE and WSRC upon which sound human and ecological risk analyses can be conducted.

PAR Pond. Data analyses continue on the effects of the PAR Pond draw down and subsequent refill on actinide availability. Most recently, activity concentrations and plant/soil concentration ratios (CRs) of ^{239,240}Pu, ^{241}Am, ^{244}Cm, ^{232}Th, and ^{238}U were determined for three vegetable crops grown on the exposed lake bed. Significant differences in activity concentrations and CRs exist between actinides and between crops. Turnip greens exhibited the highest uptake for each of the actinides measured, while corn kernels had the lowest uptakes. Geometric mean (GM) CRs ranged from 2.1×10^{-5} for ^{239,240}Pu in corn kernels to 5.3×10^{-2} for ^{241}Am in turnip greens. In general, GM CRs across all crops could be ordered as: ^{244}Cm > ^{241}Am > ^{238}U > ^{232}Th > ^{239,240}Pu. The health risks from these actinides to a hypothetical resident on the PAR sediments is being computed and will be compared to risks previously estimated for ^{137}Cs exposure. The work was in collaboration with Colorado State University (F. Ward Whicker), Argonne National Laboratory (K. Orlandini), and Washington State University (Sue Clark).

Pond A. Research was conducted on Pond A, the first settling basin down-flow of R-Reactor along R-canal as it proceeds to Pond B and PAR Pond. The work is conducted in collaboration with Colorado State University (Abraham: M. S. thesis) and SRS. The field sampling of dose distributions using TLDs and ^{137}Cs analyses of sediment cores has been completed. Because of Pond A's proximity to R-Reactor we suspected that contaminant levels would exceed those from other previously sampled aquatic systems within the P- and R-Reactor areas. We have now determined that ^{137}Cs concentrations are comparable to those found in Pond B, and suspect that the short residence time of the contaminated water in Pond A prevented substantial settling/sorption of the contaminants from occurring.

Other SRS Systems. Intensive field sampling of ponds B, C, 5, and L-Lake were done semiannually for radioisotopes. These data serve as controls or comparative sites to Par Pond.

Studies of Waterfowl Populations on the SRS

Robert A. Kennamer and I. Lehr Brisbin, Jr.

This program is designed to provide basic ecological information on both resident and migratory waterfowl populations inhabiting the SRS. In particular, studies within this program provide data on population demographics of breeding and wintering species of SRS waterfowl, wintering waterfowl species composition and distributions, and natural history traits related to survival and reproductive success. Data from this program have complemented contaminant fate and effects studies being conducted by the SREL program "Radionuclide Cycling in Vertebrates Inhabiting Contaminated Wetlands" by providing data quantifying waterfowl distributions from aerial surveys, offsite waterfowl movements, and hunter recovery data from the capture, banding, and release of SRS waterfowl. All of this information is essential for assessing SRS contaminant risks to hunters who may consume these birds.

During the winter of 1996-97, field work was completed at Par Pond as a part of a new study in which a Geographic Information System (GIS) approach will be used to spatially and temporally arrange and interpret biotic and abiotic data for waterfowl at that reservoir. Data which are being collected and stored as GIS coverages include: ^{137}Cs levels in reservoir sediment and waterfowl food resources, waterfowl behavior data (e.g., foraging rates), waterfowl whole-body and tissue-compartment ^{137}Cs levels, waterfowl food preference data, and waterfowl population distributions on the reservoir. The goals of this work will be to link the various data layers to model contaminant uptake within waterfowl populations utilizing Par Pond, and to infer potential risks to human consumers of these waterfowl. During 1996-97, whole-body counting of more than 200 ring-necked ducks *(Aythya collaris)* collected from Par Pond, and dissections of these same birds to determine food habits, age, and muscle and ingesta ^{137}Cs levels were completed. During 1996-97, work also progressed on the sorting of the more than 600 Par Pond sediment samples to remove and identify potentially important foods of waterfowl, and the preparation of representative sediment samples for ^{137}Cs determination. Aerial waterfowl surveys and behavioral data collections were also completed for this study during the 1996-97 field season.

Thirty wood duck *(Aix sponsa)* nest boxes were placed around L-Lake during early 1996. Wood duck eggs were collected from these nest boxes and boxes from Par Pond and Pond B to determine mercury contamination levels. Two manuscripts have been completed. One describes levels of mercury in wood duck eggs and their components (albumen, yolk, and shell) relative to laying sequence. The second, evaluates levels of mercury in wood duck eggs from reservoirs on the SRS.

Sub-lethal Effects of Toxicants on Organisms Occupying Coal Ash Basins and Nearby Areas on the SRS

Christopher L. Rowe, Justin D. Congdon, William A. Hopkins, and Roy D. Nagle

Coal-powered plants on the SRS produce waste (coal ash) that is stored in open basins on the site. Coal ash is rich in heavy metals and other trace elements including, As, Se, Cd, Hg, and Cr and, therefore, is of environmental concern. Animals inhabiting the coal ash basins and surrounding habitats may accumulate metals from water, sediments, and soil. Some animals complete their life cycles in the polluted areas; others migrate to different habitats and become vectors of heavy metals to unpolluted wetlands and adjacent terrestrial sites.

Several studies have been conducted to determine impacts of coal ash exposure on physiology and behavior of vertebrates and invertebrates. Substantial elevation in standard metabolic rates (estimates of energy expenditure for maintenance of physiological systems) have been observed in bullfrog tadpoles exposed to coal ash for as little as 25 d. Bullfrog tadpoles exposed to coal ash also have modified swimming performance, which increases their susceptibility to predation. It appears that multiple systems (feeding energetics, energy allocation, and predator avoidance behaviors) are severely, but sublethally, impact for bullfrogs that inhabit the coal ash-polluted areas. Furthermore, we have observed similar elevated metabolic rates in water snakes, freshwater shrimp, and adult southern toads exposed to coal ash. Thus, coal ash-induced modifications in bioenergetics of individuals may be a general response to chemical stress among a variety of distantly related taxa.

Recent, widespread interest in how pollutants impact vertebrate hormone systems prompted a study to quantify endocrinological responses of southern toads to coal combustion waste. We held adult male toads in the ash polluted site and in a reference site for two months. Blood samples were taken at predetermined intervals. Toads in the ash-polluted site maintained high circulating hormone levels; toads in the reference site experienced a peak in hormone levels during the breeding season followed by a decrease to normal levels. These results indicate that some aspect of the coal ash-polluted site causes modifications to the endocrine system that may be energetically costly to individuals.

Studies are underway to identify endocrinological impacts of coal ash on American eels and common carp, to quantify maternal transfer of metals from female water snakes to their offspring, to quantify effects of maternal exposure to coal ash on energetics of juvenile water snakes, and to quantify pollutant uptake and physiological responses of juvenile water snakes fed known amounts of contaminated and uncontaminated food.

Wildlife Studies of Vertebrates: Population Biological Effects of Environmental Perturbation

Michael H. Smith

Organisms live within a constantly changing environmental framework that provides the overall structure of the ecological and genetic components of populations. Human society has impacts on the environment that other organisms must respond to. The overall focus of our research has been the understanding of wildlife species population ecology and genetics in response to environmental perturbations. These perturbations may be caused by human activity or by non-human influences. The anthropogenic perturbations are both a result of plant operations and the broader scale changes brought about by human society. Our research, while primarily focusing on impacts due to plant operations, includes both non-human perturbations and human induced changes outside of plant operations. This allows us to place the impacts of plant operations into a realistic ecological perspective at the appropriate spatial and temporal scales.

Population studies on the SRS have utilized a wide range of wildlife species. During the last year, papers describing the ecological genetics of tree frogs (McAlpine and Smith 1995) and turtles (Scribner *et al.* 1995), the reproductive biology of a salamander and newt population (Krenz and Sever 1995, Sever *et al.* 1996a,b) and life-history variation in fish (Belk 1995) and mammals (Belk and Smith 1996) on the SRS have appeared. We have broadened the scope of our analyses to include the use of DNA unwinding analysis to examine genetic effects of environmental toxicants. A paper analyzing the genetic structure of wild turkey populations on the SRS has been published in *The American Midland Naturalist* (Boone and Rhodes 1996) and three other papers using mosquitofish as a model organism to understand genetic response to acute environmental stress (Kandl and Thompson 1996, Meffe et al. 1996) and inbreeding effects (biotic stress) (Richards and Leberg 1996) have also been published. The results of additional experiments on the effects of environmental perturbations on the genetic structure of mosquitofish populations are currently being prepared for publication. Experiments expanding the scope of analysis of genetic effects to quantitative characters and response to chronic stress are continuing, also using mosquitofish as a model organism. Current efforts are focusing on the development of inbred lines and the development of randomly amplified polymorphic DNA (RAPD) markers for the development of evolutionarily relevant biomarkers.

The scope of our research also includes broader-scale studies in order to put our experimental results in a definable ecological and geographic context. Papers have been published over the last year examining the genetic structure of reintroduced turkey populations in Kansas (Rhodes *et al.* 1995), introduction and hybridization of bass (Avise et al. 1997), and life-history characters of moles (Hartman 1995) and shrews (Whitaker *et al.* 1994). Papers have also been published that allow us to place our mosquitofish experiments in a better regional (Hernandez-Martich *et al.* 1995) and global perspective (Meffe et al. 1995, Richards and Leberg 1996). Recently completed analyses on the hybridization of mosquitofish species (one of which

is endangered) have revealed a complex and non-linear relationship between the genetic and phenotypic effects of hybridization. Many of these studies, especially those involving species introductions and hybridization, are important for larger scale plant effects such as the L-Lake drawdown which has the potential for large-scale effects. These broader scale studies allow us to view the variation in wildlife populations on the SRS within the proper spatial and temporal framework.

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Genetic and Demographic Analysis of White-tailed Deer

Michael H. Smith and Ronald K. Chesser

Studies are continuing on the population ecology and population genetics of the SRS deer herd in the context of plant operations. The focus of this research has thus been threefold. First, to try and fill any gaps in knowledge of the ecological and genetic responses of the SRS deer herd to plant operations. Second, to analyze the variation of ecological and genetic parameters in time and space for the SRS deer herd. Third, to place the SRS deer herd in the proper geographic and temporal context by extending analyses beyond the spatial boundaries of the SRS and backward in time before modern anthropogenic factors affected the deer herd. In addition, the SRS deer herd is being used as an example to extend both theoretical and practical aspects of wildlife ecology and management.

Several gaps have been filled in our biological knowledge of the SRS deer herd over the

past year. The first involves the use of white-tailed deer as a model organism to assess stress responses of individuals and the effect such responses have on underlying population processes. Recent advances in stress ecology indicate that organisms may have a suite of generalized responses to environmental stress, whether that stress is of human origin or not. Two papers have been submitted that use fluctuating asymmetry as a measure of stress in deer. These papers examined age related changes in the effects of stressors and correlations between anthropogenic and other stressors. A third paper will be submitted that will examine the relationship of stressors on females to the development and survival of their offspring. Analyses for that paper are currently being performed.

Populations of organisms are not static in time or space, especially large, vagile vertebrates. The SRS deer herd provides a unique opportunity to document such changes because of the length of time for which the herd has been under study. A paper currently in review by *The Journal of Heredity* shows how correlations between genetic loci can exhibit a large range of variation, and this variation can be used to indicate periods when unique events may be impacting a species. Another, paper, submitted to the journal *Evolution*, showed that estimates of individual genetic variability based upon allozymes are not comparable to those based upon microsatellites. An analysis has been completed of several years of data concerning car-deer accidents on the SRS. One popular article has been published and another technical article has been submitted. A GIS database is being developed placing the car-deer accident locations in order to analyze the effects of land-use patterns on the SRS in relation to the frequency of accidents between automobiles and deer. We are also refining our ability to analyze the spatial components of other aspects of white-tailed deer management and ecology by cooperating with SRFS and other SREL researchers in a program to place deer hunt stand locations into a GIS database using GPS technology. Approximately 40 percent of all the stand locations have been entered into a spatially explicit database.

The previous data cannot be reliably used to make inferences regarding the impacts of plant operations on the SRS deer herd until they are placed in the proper spatial and temporal context. A recently submitted paper has used genetic data from allozymes and mitochondrial DNA to look at the genetic structure of deer populations in Georgia and South Carolina including the SRS deer population. This work has been expanded to include mini-satellite DNA analysis to provide finer scale resolution of spatial genetic patterns on the SRS. On this scale of resolution, the genetic structure of the SRS deer population does not appear to have been affected by plant operations. In order to use while-tailed deer as an indicator species of radiological effects on the SRS. Techniques based upon single-stranded conformational polymorphisms (SSCP) are being refined to rapidly screen a large number of individuals for genetic anomalies prior to complete sequencing of the affected gene segment. This work is being pursued as part of the ongoing plant monitoring as well as part of a recently submitted proposal (DOE EMSP).

The SRS deer herd is also being used as a unique example of a population that has been studied ecologically and genetically for an extended period of time (currently 31 years). This allows it to be used for extending both ecological theory and wildlife management practices. An

invited paper for the journal *Forest Genetics* that reviews the implications of genetic heterogeneity for wildlife management and conservation biology is currently in press (Smith et al., *in press*). In this paper the SRS deer herd is used as the principal model for the application of ecological and genetic data in the management for wildlife species that maintain intimate contact with human society.

During the last year we have continued to gather data from the annual hunts. Data collected from this year's deer hunts have been added to the SREL database and are being used to provide population estimates, historical population trends, and population projections to SRFS and WSRC personnel when requested. Currently, SRS has the only complete database containing individual physical characteristics of deer, radiological assessments, kill location and genetics. The information in this database is crucial for continued enlightened management decisions for the SRS deer herd. We have also continued to make our data more accessible to other groups on site and are continuing to assemble and maintain a unified database that will contain information from the deer hunts, genetic analyses, and HP monitoring activities as well as car-deer accidents and be accessible across the site-wide network.

E. Environmental Outreach and Education

J. Whitfield Gibbons

The Division of Environmental Outreach was created at SREL during 1991. The program is designed to enhance SREL's overall mission of acquiring and communicating environmental knowledge and addresses DOE's current focus on environmental issues. In 1996, it received recognition from the Council for the Advancement and Support of Education, which honored the outreach program with an Award of Excellence in its District III (Southeast) competition.

The Environmental Outreach Division presents talks to local schools, civic groups, and other organizations, averaging four presentations per week and one tour per week. The Division has been responsible for managing the Laboratory's education program and developing an enhanced public awareness of environmental issues on the SRS and ongoing ecological research.

During the past year, SREL scheduled more than 300 lectures, 47 tours, 23 exhibits and 31 workshops. This brought the total number of people reached to over 103,000. Topics for these presentations include animal adaptation, plants and wetlands, local ecosystems and conservation, classification and careers in ecology and research.

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. Other presentations offered include tours of the lab and surrounding field sites, exhibits and workshops offered to the general public. Outreach also has distributed hundreds of copies of educational products and materials nationwide to schools, organizations and the general public. Educational materials include a full color poster that describes the life history of several species of freshwater turtles along with a teachers guide, and the "Outdoor Classroom Planning Guide."

The public relations program has included the distribution of news releases to a regular list of about 500 media affiliates, officials of DOE, and the University of Georgia. The program also has promoted various research projects through coverage in local and national media and has worked to enhance the laboratory's internal communications. Included among these have been coverage of SREL research by CNN, *U.S. News and World Report*, Associated Press, *BioScience, Earth Magazine, National Wildlife Magazine*, and National Public Radio. This program also has been responsible for planning and promoting special events, including tours for dignitaries and workshops for the general public. Ongoing projects include an internal laboratory newsletter, published on a weekly basis, and an increased number of video projects. A 27-minute six-projector automated slide presentation about SREL research has become a regular part of SREL tours.

This program also has produced and distributed three publications: *Outdoor Classroom Planning Guide , Biodiversity: Prospect & Promise for the Savannah River Site and The National Environmental Research Park at Savannah River Site: Serving an Essential Mission for 25 Years.* The Guide gives instructions for setting up a variety of outdoor classroom stations and outlines activities and investigations in which teachers can 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. This publication received the Best PR Magazine award from the CSRA Chapter of the Society of Professional Journalists. The NERP brochure highlights 25 years of research associated with the NERP program at the Savannah River Site. Other projects in progress include a wetlands poster and a new set of fact cards.

F. National Environmental Research Park Program

Nat B. Frazer

The Savannah River National Environmental Research Park (NERP) is an outdoor laboratory for study of the environmental impacts of human activities. Because public access to DOE land is limited, environmental research projects can be carried out on the SRS with a minimum of interference. The NERP is not simply a site to conduct research, but also should have programs which address the following general objectives: (1) development methods to quantitatively and continually assess and monitor the environmental impact of human activities; (2) development of methods to estimate or predict the environmental response to proposed or ongoing 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-OHER in Washington D.C. However, the final disposition of the NERP program has fallen to local DOE officials because it no longer is supported nationally by DOE's Office of Energy Research. This past year, proposals were sought and reviewed by a committee composed of four SREL scientists (one from each research group), a representative from the Savannah River Forest Station, and the NERP Director. The NERP Committee received nine proposals and was able to fund the top three. The funded projects were:

1. L.A. Donovan (UGA), C.J. Peterson (UGA) and K.W. McLeod (SREL) "Role of fire management in species composition, distribution of soil resources, and plant resource status for fall-line sandhill oak communities."

2. T.S. Risch (Auburn U.), S.C. Loeb (USDA Forest Service, Clemson U.), and R K. Chesser (SREL) "Impacts of southern flying squirrels on nesting behavior of red-cockaded woodpeckers."

3. J.M. Novak (SREL), M.H. Smith (SREL), and C. Theodorakis (Oak Ridge) "Development of evolutionarily relevant ecotoxicological biomarkers in an aquatic sentinel species, the eastern mosquitofish (*Gambusia holbrooki*)."

In addition to funding the research proposals, the SRS NERP program participated in two activities celebrating the 25th Anniversary of the Savannah River National Environmental Research Park. These activities enhanced the recognition of NERPs on a regional and a national level. In April 1997, Dr. Nat Frazer, SRS NERP Director, was invited to give the Plenary Lecture at the 58th Annual Meeting of the Association of Southeastern Biologists. His presentation highlighted the contributions and achievements of DOE's NERPs in the Southeastern states: the Savannah River Site in South Carolina and the Oak Ridge Reservation

in Tennessee. SREL also was asked by DOE's Office of Energy Research to take the lead in preparing a poster on the accomplishments of all seven of DOE's NERPs to celebrate DOE's 50th anniversary of sponsoring Biological and Environmental Research, "Serving Science and Society into the New Millennium: The Legacy and Promise of DOE's Biological and Environmental Research." The poster by Gary Wein, Nat Frazer, Tracy Rea, Deno Karapatakis, and Felicia Munson, was entitled "Precious Legacies of the Cold War: DOE's National Environmental Research Parks" and was displayed in the rotunda at the National Academy of Sciences in Washington, DC, in May 1977.

DOE Research Set-Aside Areas

Charlie E. Davis

The purpose of the Set-Aside Program is to maintain areas on the Savannah River Site (SRS) that represent habitats which are unique or native to the region, offer protection to rare, threatened, and endangered biota that inhabit these areas, and provide sites on the SRS that are conducive to long-term ecological research. In addition, these relatively undisturbed areas serve as control sites for evaluations of the impacts of SRS site operations and forest management activities. 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 National Environmental Research Park (NERP) Program.

The focus of the Set-Aside Program this past year has been on completing a NERP document which details the history of the SRS Set-Aside Program and contains profiles of each of the 30 DOE Research Set-Aside Areas. The profile of each Set-Aside contains a description and history of the Area, information on the vegetation communities and soil types found there, lists of sensitive flora and fauna documented from the Area, locator and resource composition maps, lists of ecological research publications associated with each Area. SREL's Geographic Information System (GIS) coverage for the Set-Aside areas was updated to include a characterization of the vegetation communities found in each Set-Aside Area. All appropriate SRS GIS coverages were incorporated into this vegetation coverage. Maps generated from this coverage will appear in the final NERP publication, which is scheduled for publication in July, 1997.

Cooperation between SREL and the SRFS continued this year as these the two organizations cooperated with GIS verification of some Set-Aside boundary lines that were concordant with the boundaries of planned SRFS timber management activities. Approximately 4.7 miles of Set-Aside boundary line was GPSed by the SRFS in the E. P. Odum Wetland Set-Aside during the past year. Periodic inspections of Set-Aside boundary postings were conducted by SREL where potential land-use conflicts were anticipated and approximately 5.75 miles of Set-Aside boundary line were refurbished with signs.

SREL's Set-Aside research coordinator continued to participate as an ID team member in the SRFS's prescription review process, which occurs during the development of natural resource management plans for Site timber compartments. This coordination and planning with the SRFS is successful in verifying Set-Aside and timber stand boundary line concordance with GIS coverages, in updating sensitive plant population surveys conducted in Set-Aside areas, and in addressing potential conflicts with forestry activities adjacent to Set-Aside Areas. Pre-planning activities for the SRFS's prescribed burning program continued.

SREL continued numerous long-term plant and animal studies in Set-Asides and initiated new studies this fiscal year, including: the response of old-field plants to plant and soil resource density and pattern, stream invertebrate community studies, and expansion of ecotoxicology studies associated with Site ash basins. In addition, Carolina bays in Set-Asides are being used as proxies in studies of the hydrology of man-made catchment basins; these studies will support future efforts to remediate such basins. Groups other than SREL also continue to use the Set-Aside Areas. Research continues on coarse woody debris decomposition, softmast production in bottomland hardwood forests, the role of fleshy fruit production, consumption, and dispersal on promoting biological diversity, and archaeological investigations around Carolina bays. Both the SRFS and SREL continued to use Set-Aside Areas in education and outreach programs.

During the past year SREL and the Set-Aside Task Group requested and were granted two new areas as replacement Set-Asides for the original Cypress Grove (Area No. 9). Cypress Grove was deleted from the Set-Aside Program because it is documented to be contaminated from Site operations; additionally, the vegetation in this tract no longer is representative of a mature swamp forest. Replacement Area No. 9A, the Stave Island Site, and Area No. 9B, the Georgia Power Site, both are representative of a swamp forest, but each differs in its particular attributes; rather than choosing a single Area for inclusion as a Set-Aside, both of these Areas were added to the Program. Additional action by the Set-Aside Task Group resulted in the transfer of two acres of the UGA Old Laboratory Site Set-Aside (Area No. 2) to the SRFS, for development of an environmental sciences field station for use by Historically Black Colleges and Universities. The Set-Aside GIS coverage will be amended to reflect both of these changes in the Program that have occurred during the past year.

Recent publications that used Set-Aside Areas:

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G. 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.

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. Since 1967, an average of six students a year have completed graduate studies at SREL and over 190 dissertations and theses have been written. The Undergraduate-Research Experience for Undergraduates, funded by the National Science Foundation, is in its second year and this year we sponsored 10 students. In order to extend this program a new proposal to NSF is planned for this fiscal year.

Since 1985, our graduate students have won over 110 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.

The SREL Education Program was also revised during FY'97. The new program will continue its commitment to support long-term graduate students previously supported by the old program. However, beginning in FY'98, the new program will entitle each SREL faculty member to only one graduate student funded through the Education Program. Additional graduate students may be supported by the faculty project budgets within the four research groups funded by the DOE Cooperative Agreement, or through outside grants awarded to faculty. All SREL graduate students to be supported by the DOE funds under SREL's Cooperative Agreement, will be reviewed by the Education Committee prior to admittance and be required to conduct research relevant to the DOE mission. This applies both to students supported through the Education Program as well as to students supported by projects within the four research groups funded by the SREL Cooperative Agreement with DOE. Students' progress towards completing degree requirements will be evaluated annually by the Education Committee, with time limits of up to five years for Ph.D. students and three years for Master's students. The Committee consists of five faculty members and is chaired by the Head of the Education Program, who reports to the Associate Director for Research. These changes will insure the continued success of the Education Program.

We are part of the Georgia Statewide Academic and Medical System, a two-way interactive distance education system, which has the capability to be downloaded to 292 schools, colleges, universities and correctional institutions in Georgia. We are negotiating

a link to South Carolina Schools. When this link is complete we will be able to connect to any system worldwide.

Participant Institution Sponsor
Undergraduate Research PArticipation Program

Samuel J. Arey	IndianaUniversity,Bloomington, IN	Paul Bertsch
Steven Ashley	University of Georgia, Athens, GA	Kenneth McLeod
Jodi Beck	Pennsylvania State University, University Park, PA	I. Lehr Brisbin
Alexis N. Draft	Pennsylvania State University, University Park, PA	Charles Jagoe
Tara Darcy	Kalamazoo College, Kalamazoo, MI	Chris Rowe
Elizabeth Gatlin	North Carolina State University, Raleigh, NC	Peg Mulvey
Mie Lewis	Oberlin College, Oberlin, OH	Gary Mills
Minghua Nie	University of Alabama, Tuscaloosa, AL	Michael Newman
Sandra Raimondo	Pennsylvania State University University Park, PA	Justin Congdon
Ronald Small	Clemson University, Clemson, SC	Gary Meffe
Elizabeth Veomett	University of Nebraska, Lincoln, NE	Paul Bertsch
Christina Werner	Adrian College, Adrian, MI	Beverly Collins

Graduate Research Participation Program

James Abraham	M.S.	Colorado State University, Fort Collins, CO	Ward Whicker
Christopher Beck	Ph.D.	University of Georgia, Athens, GA	Justin Congdon
Viven Braslau	M.S.	Bard College, Anandale-on-Hudson, NY	Justin Congdon
Krista Clements	M.S.	University of Georgia, Athens, GA	Gary Meffe
Daniel Connor	Ph.D.	Georgia Institute of Technology, Atlanta, GA	Tom Hinton
William Hopkins	M.S.	Auburn University, Auburn, AL	Justin Congdon
Mark Komoroski	M.S.	University of Georgia, Athens, GA	Justin Congdon
Susan Miller	Ph.D.	University of Georgia, Athens, GA	Becky Sharitz
Debra Moore	Ph.D.	University of Alabama, Birmingham, AL	Whit Gibbons
Julie Murray	Ph.D.	University of Georgia, Athens, GA	I. Lehr Brisbin
Jennifer Olson	M.S	Texas A&M University, College Station, TX	Gary Mills
Gordon Plague	M.S.	University of Georgia, Athens, GA	J Vaun McArthur
Stephanie Schaeffer	M.S.	New Mexico State Univ., Las Cruces, NM	Peg Mulvey
Pamela Schultz	M.S.	University of Georgia, Athens, GA	Gary Mills
Julian Singer	M.S.	University of Georgia, Athens, GA	Becky Sharitz
Chris Tatara	Ph.D.	University of Georgia, Athens, GA	Michael Newman
Stephen Tidd	M.S.	Texas Christian University, Fort Worth, TX	John Pinder
Susan Turner	Ph.D.	University of Georgia, Athens, GA	Phil Dixon
Debra Wohl	Ph.D.	University of Georgia, Athens, GA	J Vaun McArthur
Rebecca Yeomans	Ph.D.	University of Georgia, Athens, GA	Justin Congdon
Karen Zabicki	M.S.	Texas Christian University, Fort Worth, TX	John Pinder

Doe Laboratory Graduate Fellowships

Loretta Battaglia	Ph.D.	University of Georgia, Athens, GA	Becky Sharitz
Kurt Buhlmann	Ph.D.	University of Georgia, Athens, GA	Whit Gibbons
Michael Draney	Ph.D.	University of Georgia, Athens, GA	Barbara Taylor
Adrienne Edwards	Ph.D.	University of Georgia, Athens, GA	Becky Sharitz
Robert Ford	Ph.D.	Clemson University, Clemson, SC	Paul Bertsch
Evelyn Gaiser	Ph.D.	University of Georgia, Athens, GA	Barbara Taylor
Kathryn Gubista	Ph.D.	University of Georgia, Athens, GA	Ron Chesser
Chris Harrison	Ph.D.	Texas A&M University, College Station, TX	Whit Gibbons
John Lee	M.S.	University of Georgia, Athens, GA	Whit Gibbons
Vicki Medland	Ph.D.	University of Georgia, Athens, GA	Barbara Taylor
Mark Mills	Ph.D.	University of Georgia, Athens, GA	Whit Gibbons
Thomas Risch	Ph.D.	Auburn University, Auburn, AL	Ron Chesser
Joel Snodgrass	Ph.D.	University of Georgia, Athens, GA	Gary Meffe
LeeAnn Woodward	Ph.D.	University of California, Davis, CA	Michael Newman

Divisional Graduate Students

Joe Albright	Ph.D.	University of Georgia, Athens, GA	Domy Adriano
Jennifer Brofft	M.S.	.University of Georgia, Athens, GA	J Vaun McArthur
Robert Cheney	Ph.D.	University of Georgia, Athens, GA	Barbara Taylor
Reide Corbett	M.S.	Florida State University, Tallahassee, FL	Sue Clark
Michael Garrett	M.S.	University of Georgia, Athens, GA	Gary Mills
Kevin Holloman	Ph.D.	University of Georgia, Athens, GA	Ron Chesser
John Kind	Ph.D.	University of Georgia, Athens, GA	Cham Dallas
David Henandez	Ph.D.	University of Georgia, Athens, GA	Michael H. Smith
Michelle Lakly	M.S	.Unviersity of Georgia, Athens, GA	J Vaun McArthur
Dean Lindholm	Ph.D.	University of Georgia, Athens, GA	Becky Sharitz
Jim Novak	Ph.D.	University of Georgia, Athens, GA	Michael H. Smith
Andrew Thompson	M.S	.University of Georgia, Athens, GA	Becky Sharitz
Gordon Ward	P.hD.	University of Georgia, Athens, GA	Phil Dixon
Roger Wong	M.S.	Florida State University, Tallahassee, FL	Sue Clark
Doug Wymer	M.S.	Clemson Universaity, Clemson, SC	J Vaun McArthur

Faculty Research Participation Program

Dr Mary Mendonca	Auburn University, Auburn , AL	Justin Congdon
Dr. F.Stephen Dobson	Auburn University, Auburn, AL	Ron Chesser

SREL Graduate Students Completing Degree Requirements

Ford, R. 1996
The effects of aging on the partitioning of divalent transition metals coprecipitated with iron oxides. Ph.D. Clemson University. Advisor: P.M. Bertsch

Olson, J.J. 1997
Characterization of biodegradation rates of separated diesel components. M.S. Texas A & M University. Advisor: G.L. Mills

Woodward, L.A. 1997
Fluctuating asymmetry as an indicator of mercury pollution. Ph.D. University of California, Davis, CA. Advisor: M.C. Newman

Medland, V.L. 1997. Impact of climate variability on the success of life history strategies of diapausing cyclopoid copepods. Ph.D. University of Georgia, Athens, GA. Advisor: R.R. Sharitz

Gaiser, E.E. 1997. Paleolimnological reconstruction of holocene environments in wetland ponds of the upper Atlantic coastal plain. Ph.D. University of Georgia, Athens, GA. Advisor: R.R. Sharitz

H. Research Data Archive Activities

Ronald K. Chesser and John Heuer

Environmentally responsible management of the SRS is dependent, in part, on efficient access to sound, scientifically defensible ecological data. Since 1989, SREL has been actively developing a centralized repository of research datafiles and a comprehensive database application which manages the associated "metadata" (data about data) and searchable catalogs necessary for these data to be fully accessible. The goal of SREL's Research Data Archive Activity is to utilize advanced electronic computer/communication technology, including the use of computer networks and the Internet, to effectively access important data as efficiently as possible.

During FY'97, the network application which manages the research datafile catalog underwent additional improvement and modification. Reporting routines and recommendations from laboratory research personnel were incorporated. In addition, logging routines were added to facilitate recovery of information following system failures. The scope of the original application was expanded to permit inclusion of information as discussed in the report of the Future of Long-term Data Committee of the Ecological Society of America.

Inclusion of historical and new research information continued during FY '97 and the backlog of effort from FY '96 was addressed. The Research Data File Catalog now has information which covers over 440 separate studies.

Requests for information from the archives included specific catalogs of studies for other SRS contractors and visiting researchers. The archive also served as a backup of information for laboratory personnel.

A preliminary, searchable catalog of studies from the Research Data File Catalog was included in the SREL World Wide Web intranet homepage currently under construction. When completed, this will permit anyone on site with a web-enabled computer to easily determine what studies in the SREL archive match a particular area of interest.

Studies Included in the SREL Data Archive System during FY'97

The following studies were submitted for inclusion in the SREL research data archive system during FY'97.

Adriano	Determination of arsenic species in soil solution under flooded conditions.
Adriano	Characteristics of vegetation in D-Area ash basins
Adriano	Arsenic availability in soil over time under saturated and subsaturated conditions
Adriano	Par Pond garden plot studies to determine effectiveness of soil amendments in mediating uptake of 137Cs by certain vegetable crops-
Bertsch	Distribution of metals and metalloids in biota collected from contaminated environments
Bertsch	Ionic tracer movement through the highly weathered sediments of the upper coastal plain, U.S.
Bertsch	Heavy metal partitioning during hydrous iron oxide aging
Bertsch	Surface water transport and distribution of uranium in contaminated sediments near a nuclear weapons

	processing facility
Bertsch	Physicochemical controls on non-conservative anion migration in coarse-textured alluvial sediments
Bertsch	Molecular characterization of Cr phases in contaminated soils
Bertsch	Nuclear magnetic resonance (NMR) characterization of the nonionic organic contaminant-organic matter interaction
Bertsch	A time resolved XANES study of an organo-clay redox system
Bertsch	Pyrene sorption to water soluble organic carbon as determined by fluorescence spectroscopy
Bertsch	Transport of dissolved organic matter through a sandy forest soil
Bertsch	Site specific binding environments of surface sorbed Cs on clay minerals
Bertsch	Nickel adsorption to hydrous ferric oxide in the presence of EDTA
Bertsch	Chemistry of uranium in evaporation pond sediment
Bertsch	Chemical speciation of U by micro x-ray absorption spectroscopy
Bertsch	Surfactant-modified clinoptilolite topological and thermal properties
Bertsch	Chemical controls on colloid generation and transport in a sandy aquifer
Bertsch	Molecular characterization of contaminants in soils
Brisbin	Uptake of ^{137}Cs and Hg by mallard ducks on Par Pond
Brisbin	Growth of captive American alligators fed prepared rations
Brisbin	Growth patterns of captive king snakes
Brisbin	Comparison of Eberline and muscle tissue samples for determination of ^{137}Cs concentration in alligators from Par Pond, summer 1995
Brisbin	Uptake and concentration of ^{137}Cs by American alligators at the SRS
Brisbin	Estimating energy metabolism of goldfish and southern toad from ^{86}Rb elimination rates
Brisbin	Aerial survey of American alligators at the SRS
Brisbin	^{137}Cs levels in mosquitofish from Pond B - effect of season
Brisbin	Bantam chicken ^{137}Cs kinetics
Brisbin	^{137}Cs levels of mosquitofish inhabiting a reactor cooling reservoir (Pond B, SRS)
Brisbin	Elimination of ^{137}Cs as a function of body size and temperature from Pond B largemouth bass
Brisbin	Relationship of wood duck hatch date to pairing chronology and hormone levels during autumn and winter
Brisbin	Feral dog captive population genetic/genealogical study
Brisbin	Survey of birds near selected impoundments of the SRS
Brisbin	Environmental influences on ^{137}Cs kinetics of yellow-bellied turtles
Brisbin	Christmas bird counts of SRS and some adjoining habitats
Brisbin	Behavior and ecology of primitive dogs
Brisbin	Nesting characteristics of common moorhen and purple gallinule
Brisbin	Comparison of blood and whole body elimination of Rb and Cs from channel catfish
Chesser	Effect of mercury and radiocesium contamination on DNA damage of largemouth bass
Chesser	Relationship of litter size with juvenile survival in Columbian ground squirrels collected from Washington state and Alberta, Canada
Chesser	Genetic structure of wild turkeys on the SRS
Chesser	A modeling study on the influence of inbreeding depression and rate of habitat fragmentation on population extinction
Chesser	Assessment of geographic patterns for morphometric traits
Chesser	Genetic study of 3 species of voles from Chernobyl
Chesser	Radiocesium and genetic damage in channel catfish from Chernobyl
Chesser	Effects of parental quality and egg size on growth and survival of herring gull chicks - Chincoteaque Bay, Worcester County, Maryland
Clark	Radiostrontium in calcium carbonate matrices of biological origin.
Collins	Biomass allocation in *Aristida tuberculosa* in old field ecosystems (3412, 3409, Oldlab)
Collins	Soil nutrient heterogeneity effects on early oldfield succession
Collins	Effects of soil resource heterogeneity on early oldfield succession, Memphis TN
Collins	Herbivory and plant interactions in bottomland hardwood experimental gaps
Collins	Competition among herbaceous annual plants in an old field ecosystem (3-412)
Collins	Spatial distribution of forbs and grasses in field 3-412
Congdon	Foraging ecology and behavior of the western whiptail lizard, *Cnemidophorus tigris*
Congdon	Genetics of painted turtles
Congdon	Effects of trace elements on metabolism of bullfrog tadpoles
Congdon	Comparison of swimming behavior and predator avoidance in bullfrog tadpoles collected from a polluted vs.

	unpolluted site
Congdon	Bullfrog tadpole deformities
Congdon	Short-term growth and survivorship in postmetamorphic southern toads *(Bufo terrestris)*
Congdon	Tadpole oral deformities associated with coal ash deposition - effect on grazing ability and growth
Congdon	Amphibian egg lipid study
Congdon	Behavioral, thermal, and metabolic characteristics of wintering *Anolis carolinensis* from South Carolina
Congdon	Size-dependent microhabitat partitioning by non-breeding *Anolis carolinensis* lizards.
Congdon	Reproductive cycle of the Jamaican lizard, Anolis opalinus
Congdon	Behavioral profile of free-ranging male lizards, *Anolis carolinensis*, across breeding and post-breeding seasons
Congdon	Behavior and time budget of free-ranging female *Anolis carolinensis*
Dixon	Carolina bay vegetation study
Dixon	Modeling characteristics of sunflecks
Gibbons	Clutch size variation in snakes
Gibbons	Reproductive cycles in the black swamp snake.
Gibbons	Annual cycle of secretion and sperm storage of the salamander, *Ambystoma opacum*
Gibbons	Flow cytometry study of gopher tortoises
Gibbons	Habitat use by slimy salamanders *Plethodon glutinosus* in the South Caroline sandhills
Gibbons	Thermal biology of digestion in rubber boas
Gibbons	Larval duration in *Hyla squirella*
Gibbons	Characteristics of the reproductive biology of paedomorphic salamanders
Gibbons	Study of female cloacal anatomy of paedomorphic *Ambystoma talpoideum* collected from SRS
Gibbons	Head and body temperature differences in free-ranging rubber boas
Gibbons	Reproduction of crawfish frog
Gibbons	Daily body temperature variation in free-ranging rubber boas
Gibbons	Some aspects of the spatial distribution and natural history of brown water snakes, *Nerodia taxispilota*
Gibbons	Occurrence of pine woods snake on the SRS
Gibbons	Frog cladistics study
Gibbons	Responses of invertebrate herbivores to stinging trichomes of *Urtica dioica* and *Laportea canadensis*
Gibbons	Effect of flag markers on attraction of turtle nest predators
Gibbons	Assessment of a technique for measuring venomous snakes
Gibbons	Incidence of shell disease in turtles from Lake Blackshear, GA
Gibbons	Turtle orientation - field tests of water-finding ability in adult yellow-bellied pond sliders, *Trachymes scripta*
Gibbons	Nesting behavior of the common mud turtle
Gibbons	Diel nest temperature and nest site selection for two sympatric species of freshwater turtles
Gibbons	Effects of harvesting on size structure of red-eared sliders in LA
Gibbons	Flow cytometric analysis of slider turtles from seepage basins
Gibbons	Location of aquatic turtle nests relative to a Carolina bay
Hinton	Foliar adsorption of resuspended ^{137}Cs - Chernobyl
Hinton	Radioecological characterization of the R-Reactor cooling water basins
Hinton	Radiographic determination of fecundity in turtles
Jagoe	Fish health assessment study
Jagoe	Relationship of gill Na, K ATPase activity in largemouth bass with mercury contamination
Jagoe	Effect of Hg exposure on morphology of mosquitofish gills
Jagoe	Quantitative comparisons of the morphology and ultrastructure of erythrocyte nuclei from 7 freshwater fish species
Jagoe	Relationship between precipitation and surface water chemistry in three Carolina bays
Jagoe	Effect of Al and pH on dragon fly larvae predation of tadpoles
McArthur	Organic matter retention by macrophytes
McArthur	Distribution of Asiatic clam on the SRS
McArthur	The genetic structure of a lotic population of *Burkholderia (Pseudomonas) cepacia*
McArthur	Role of structural complexity and periphyton on the colonization of macrophytes by macroinvertebrates
McArthur	Genetic structure of *Cheumatopsyche* spp. caddisflies from Upper Three Runs Creek
McArthur	Roles of leaf quality and season in leaf decomposition in Tinker Creek
McArthur	New Production Reactor - macroinvertebrate study
McArthur	Linkages between trophic variability and distribution of *Pteronarcys* spp. along a stream continuum
McArthur	Comparison of methods of DNA extraction from stream sediments

McArthur	Identification of aquatic *Burkholderia (Pseudomonas) cepacia* using species-specific rRNA gene probes
McArthur	Comparative colonization rates
McLeod	Effect of *Vaccinium* cover on oak regeneration.
McLeod	Photosynthesis and water relations of four oak species: impact of flooding and salinity.
McLeod	Four Mile wetland restoration: Transplanting techniques in standing water
McLeod	Is willow removal beneficial to outplanted seedlings.
McLeod	Random planting vs. planting in sites of reasonable hydrology for a particular species
McLeod	The effects of various weed control methods on the survival and growth of outplanted seedlings in Four Mile delta
Meffe	Quantitative genetics of life history traits of mosquitofish
Meffe	Carolina bay fish assemblages
Meffe	The status of scrub and scrub jays in Brevard Co. FLA
Meffe	Growth and development of southern toad tadpoles
Meffe	Dynamics of lipid storage of mosquitofish during the winter months
Meffe	Effect of certain habitat parameters on life history characteristics of mosquitofish.
Meffe	Estimating the hidden cost of reproduction in mosquitofish
Meffe	Plasticity of lipid storage in *Pseudacris crucifer* tadpoles
Meffe	Reproduction of dollar sunfish under predatory threat
Meffe	Nest association of dusky shiners *(Notropis cummingsae)* and redbreast sunfish *(Lepomis auritus)*
Meffe	Maintenance of sex in a clonal/sexual species complex (Poeciliidae: *Poeciliopsis*)
Meffe	Quantitative genetics of Critical Thermal Maxima (CTM) of mosquitofish
Mills	Soil bioremediation study - diesel fuel and nickel
Mills	Free and humic bound carbohydrates leached from leaves of four floodplain tree species.
Mills	Sorption of hydrophobic organic compounds to residual diesel oil in aquifer materials
Mills	A comparison of lipids from soils from bottomland, midslope and upland habitats
Mulvey	Effect of chronic mercury stress on growth and reproduction of mosquitofish, *Gambusia holbrooki*
Mulvey	Developmental stability as a measure of sublethal toxicity
Mulvey	Inter- and intraspecific genetic variation of snails in the genus *Biomphalaria*
Newman	Effect of chronic lead exposure on *Helix aspersa*
Newman	Developmental stability of chironomid larvae as an indicator of sediment mercury contamination
Newman	Distribution of Asiatic clams in a metal contaminated sediment
Newman	Elimination of methyl mercury from the blood and plasma of selected fish species
Newman	Effect of mercury exposure on allozyme polymorphism of chironomids
Newman	Elimination of metal salts from the blood of channel catfish after intravascular injection
Newman	Predicting relative metal toxicity with ion characteristics for nematodes
Newman	Predicting relative toxicity of metals to bacteria using ion characteristics
Newman	Use of microtox bioluminescence assay techniques to predict relative toxicity and interactions of divalent metal ions
Pinder	Topographical influences on the distribution of Loblolly Pine in Bastrop State Park, Bastrop, TX
Pinder	Factors affecting the limited reproductive success of loblolly pines in the large old field, 3-412.
Pinder	Bathymetry as a controlling factor in macrophyte development in Pond B
Pinder	Distribution of ^{137}Cs in sediments of the littoral zone of Pond B - a former reactor cooling pond.
Pinder	Foliar uptake of ^{137}Cs from the water column by aquatic macrophytes in Pond B, SRS
Pinder	Remote sensing study of habitat change in Madagascar - long-term analysis of *Pyxis planacauda* using remote sensing
Pinder	Variance components of radiocesium concentrations in plants inhabiting a contaminated floodplain (Steel Creek)
Pinder	Hardwood succession in a large old field: A case study in South Carolina (Field 3-412)
Pinder	Corresponding development of plant and phytophagous orthopteran communities during southeastern old-field succession
Sharitz	Daily water levels at Pen Branch boardwalk
Sharitz	Vegetation changes and land use legacies of depression wetlands of the western coastal plain of South Carolina: 1951 - 1992
Sharitz	Bottomland hardwood seedling regeneration study - population dynamics of advanced seeding regeneration in four floodplain forests
Sharitz	Use of pressure transducers for measuring positive potential below the water table
Sharitz	Effect of altered hydrologic regime on growth of bald cypress

Sharitz	Seed dispersal of the wetland milkweed, *Asclepias perennis*
Sharitz	Early germination greenhouse study
Sharitz	Seed predation in *Baptisia lanceolata* and *B. perfoliata*
Sharitz	Red maple seedling survival and growth: Effects of root competition
Sharitz	Seedling photosynthesis and growth - HWCTR 1987
Sharitz	Vegetation, biomass, and nitrogen pools in a spruce-fir forest of the Great Smoky Mountains National Park, USA
Sharitz	Effects of flooding on growth and survival of seedlings
Sharitz	Effects of light on photosynthesis and growth of seedlings
Sharitz	Effects of root competition on growth and survival of seedlings
Sharitz	Effects of flooding and root competition on growth and survival of 5 bottomland species
Smith	Assessment of metal uptake and genetic damage in small mammals inhabiting the D-Area fly ash basin
Smith	Genetic variation of mosquitofish from three river drainages in Georgia and Florida
Smith	Genetic variability of mosquito fish across its native range.
Smith	Genetics of mosquitofish from the Altamaha and Ogeechee River drainages
Smith	Responses of mosquitofish to acute environmental stress - family effects vs. inbreeding and genotype effects
Smith	New Production Reactor pre-operational monitoring mammal survey
Smith	Cytonuclear genetics experiment of fish hybrid zones inside Biosphere 2
Smith	Demographic and population genetic structure in the eastern mole
Smith	Genetic structure of a wintering population of American coots on the SRS
Smith	Asymmetry and genetic variability in a natural population of house mice from Caithness, Scotland
Smith	Genetic effects of experimental habitat fragmentation in the root vole, *Microtus oeconomus*
Smith	Genetics of white-tailed deer collected from Chickamauga Battlefield Park.
Smith	Genetics of black bear from several locations in SE USA
Smith	Genetic variation in *Peromyscus lecopus* and *P. gossypinus*
Smith	Some aspects of the ecology of the short-tailed strew collected from Mill Creek, SRS
Smith	Variation in life history and genetic traits of Hawaiian mosquitofish populations
Smith	Genetics of nesting bald eagles from Colorado and Ontario
Smith	Effect of food and cover on space use by sparrows
Smith	Genetic variation in the cotton mouse
Strojan	D-Area leachate migration study
Taylor	Diatoms of Carolina bays in South Carolina
Taylor	Aquatic invertebrate abundance and biomass at Rainbow Bay on the SRS, during 1992 and 1993
Wein	Seedbank and vegetation of a constructed wetland
Whicker	^{137}Cs concentration in Pond A sediment cores

I. Safety and Quality Assurance

Environmental Health and Safety Program

Donald R. Mosser and Warren J. Safter

The Savannah River Ecology Laboratory (SREL) is committed to providing a safe and healthy work environment where risks to the occupational safety and health of its personnel remain as low as is reasonably achievable.

SREL Environmental Health and Safety (EH&S) Services has played an integral role in the maintenance of existing facilities and in planning and acceptance of renovations and new SREL construction. Potential physical, chemical, and biological hazards were identified during periodic facility inspections and corrective actions were initiated through SREL's supervision, management and SREL Maintenance Division Work Order System. Monitoring of fume hoods, exposure to radiological, and physical agents, and emergency equipment was accomplished. As a result of an SREL reduction in force, the total committed full time equivalent (FTE) persons for SREL EH&S Services has been reduced from approximately three to two, with one of the remaining two FTE committed to managing both the SREL environmental and occupational safety and health programs.

SREL EH&S Services has been an active participant in SREL's Necessary and Sufficient Process, providing information and input to the Convened Group and the Identification and Confirmation Teams. SREL completed the Necessary and Sufficient Process and as a result adopted a set of Work Smart Standards with respect to EH&S operational performance and requirements. Implementation of the newly adopted Work Smart Standards continues to be a top priority for SREL and EH&S Services. In conjunction with the Necessary and Sufficient Process, the SREL Safety Committee revised the SREL Safety Manual to facilitate incorporation of the Work Smart Standards into SREL's existing policies.

SREL Safety information, forms, policies and procedures continue to be disseminated and enhanced by presentation through SREL intranet web services. Lessons learned information, product safety alerts, hazard alerts, and training opportunity information continue to be disseminated over GroupWise (electronic mail system), in the Grapeleaf publication, and by posting information on the Safety Bulletin Board. Additionally, pamphlets and periodicals were made available and safety information was placed in break rooms and the reception area.

Formalized training, which includes job-specific training for new personnel, has been revised and enhanced. For those personnel who required it, training was provided in driver safety, hearing conservation, and boating safety. Radiation workers were trained under the SRS program with additional training at SREL in X-ray and sealed source safety. Training also was offered in first-aid and CPR, sports medicine, and laboratory safety.

Environmental Program

Vivian Harper

During FY '96, the University of Georgia's Savannah River Ecology Laboratory voluntarily participated in the Department of Energy's Necessary and Sufficient Process, an extensive review of the environmental, safety and health hazards involved in all aspects of its work. This review led to the development of a new set of "work smart standards" which will enable the laboratory to operate more efficiently while maintaining a commitment to environmental stewardship and worker health.

The Savannah River Ecology Laboratory completed its participation in the Savannah River Site's Rock Hill Work-out Initiative. With the help of SREL researchers, the SRS was able to develop and implement a "right-sized" monitoring program. SREL aided the SRS in saving over $8 million in environmental monitoring costs.

The Savannah River Ecology Laboratory began development of a new Environmental Management System based on ISO14001, an international standard for environmental management. With its unique responsibility to the Department of Energy mission, SREL will probably be the first university facility to obtain ISO14001 certification.

To ensure regulatory compliance, the Savannah River Ecology Laboratory participated in 58 environmental assessments. The most significant assessment involved the identification of all environmental laws and regulations relevant to SREL's activities for the Necessary and Sufficient Process, which resulted in the development of new standards under which the Laboratory will operate.

Quality Assurance Program

David .R. Burrows

SREL has continued to maintain a formal, DOE-approved quality assurance (QA) program based on the requirements of DOE Order 5700.6C. The program is unique within the DOE complex in that it was created directly from the requirements of that DOE Order, rather than being adapted from earlier, nuclear facility QA requirements. The program is devoted to assuring the continuing quality of SREL research and is managed by a dedicated QA program coordinator.

Monthly inspections and quarterly independent assessments of research activities are performed. Vendors providing products or services that affect SREL research are assessed to ensure the quality of their support. Every new employee receives training on the applicable portions of the QA program.

The SREL QA program has been the subject of a number of conference papers and journal articles. SREL has been directly involved in the development of a number of national consensus standards related to research quality assurance and quality management.

A booklet providing guidance to SREL researchers titled "SREL Good Research Practices" was written and distributed to SREL research personnel. This booklet discusses research concepts and context, research logistics; and the conduct of research. Copies are available from Gary Wein.

SPECIAL ACCOMPLISHMENTS OF FACULTY, STAFF, STUDENTS AND ADMINISTRATION

Noteworthy Events and Special Activities

A major activity for the SREL in FY '97 was implementation of a new contract for the operation of the Savannah River Ecology Laboratory (SREL). During FY '96 the Department of Energy (DOE) converted the Management and Operating (M&O) contract to a new five year Cooperative Agreement with the University of Georgia. SREL was the first Management and Operating (M&O) contractor throughout the Department of Energy to change to a Cooperative Agreement. The M&O contract under which SREL had operated through the UGA Research Foundation had been in effect since 1973, was the longest running contract on the Savannah River Site. The new Cooperative Agreement was signed on June 18, 1996. This agreement provides SREL greater flexibility in operating within the DOE structure. Under the new Cooperative Agreement, SREL will be given greater ability to work with the State of South Carolina regulators in complying with the various environmental and radiological statues.

Many of the new regulatory requirements of the Laboratory's operation under the Cooperative Agreement will be determined by the new Necessary and Sufficient (N&S) Process set up by the Department of Energy. The N&S Process is an example of the DOE commitment to using integrated management systems to ensure adequate protection for workers, the public, and the environment. The objectives for this process were the development of a set of standards which will provide protection to SREL personnel, the public, and the environment. Only those aspects of SREL that deal specifically with the Environment, Safety, and Health programs were considered at this time. A convened group made up of both SREL and DOE representatives selected an Identification Team (IDT) of SREL employees along with a DOE N&S Process coach. All IDT members received training in the N&S Process and met with experts in specialty areas such as radiation safety. The IDT first discussed each aspect of SREL operations to determine what hazards were present and then determined which standards were most appropriate for specific operations. The following safety and environmental areas were identified by this process:

- Safety Standards
  - Fire Safety
  - Ionizing Radiation
  - Occupational Safety
  - Industrial Hygiene
  - Ergonomics
  - Biosafety
- Environmental Standards
  - Air Emissions
  - Effluent Discharges
  - Wells

General Environmental Protection
Waste Management
Hazardous Materials Transportation and Handling
Emergency Preparedness
Herbicide/Pesticide Use

The overall process has been reviewed and was approved on March 20, 1997 by a Confirmation Team composed of SREL and DOE regulatory personnel. The N&S Process standards were approved on June 27, 1997 by Dr. Judith Bostock of the DOE.

The DOE has asked SREL to focus its future research efforts on solving problems that will aid cleanup efforts at the Savannah River Site. In order to meet these new mission objectives, SREL has reorganized into four new interdisciplinary program areas: (1) Advanced Analytical Center for Environmental Sciences (AACES); (2) Ecotoxicology, Remediation, and Risk Assessment (ETRRA); (3) Ecological Stewardship and (4) Radioecology. Within each of these four research groups new programs are being developed in FY '98 for initiation in FY '99.

The Advanced Analytical Center for Environmental Sciences (AACES), established in December 1994 through ERDA Task Order 94-064 to the University of Georgia, Savannah River Ecology Laboratory, completed its third year of operation. The objective of this group is to function as an advanced research and development organization in environmental science and engineering. The AACES mission is to provide the environmental science and engineering communities at the SRS, other DOE and DOD sites, regional and national colleges and universities, and industry with ready access to state-of-the-science analytical, spectroscopic, and computational modeling techniques as well as with the support to generate and interpret data from complex environmental samples. The AACES has (1) completed a comprehensive business plan; (2) created seven positions including, three Ph.D. scientists, three M.S. scientists, and a clerical position; (3) established a nationally-recognized advanced R&D center for environmental research; (4) established an important resource for regional colleges and universities; (5) established an active education and outreach program; and (6) leveraged $2.14 M in contracts and grants from collaborations with researchers at universities, national laboratories, and industry. The AACES scientists currently have more than $6 M in pending proposals.

Dr. Justin D. Congdon organized and conducted the Fourth Annual SREL Symposium on the Environment titled "Resource Allocation Processes: The Connection Between Individual and Population Levels of Biological Organization" in January 1997. **Drs. Michael C. Newman** and **Carl L. Strojan** organized and conducted a workshop titled "Risk Assessment: Logic and Measurement" that was held at the SREL Conference Center in August 1996. **Dr. Newman** also developed and taught a course on Quantitative Methods in Ecotoxicology at the SREL Conference Center in July 1996. **Dr. Domy C. Adriano**, along with faculty from the University of California and the U.S. Army Cold Regions Research and

Engineering Laboratory, cosponsored the Fourth International Conference on the "Biogeochemistry of Trace Elements" at the University of California, during June 1997.

During the past year SREL purchased and installed a $539,000 Fourier Transform Mass Spectrometer using matching funds from DOE and UGA Lottery Funds. This will raise SREL's analytical capabilities to a new level of sophistication, allowing the analysis of organic chemicals, such as those found in mixed wastes from contaminated sites.

Major additions to the SREL facilities were completed that will enhance the Laboratory's work in the future. The construction of a 5,000 ft^2 laboratory addition to the main Laboratory building has been finished. It will house three multiuser laboratories designed to facilitate research initiatives in Molecular Ecology, Environmental Chemistry and Bioremediation, and will triple the space available for analytical equipment. A new 5,000 ft^2 Animal Care Facility has been constructed and was occupied in January 1997. Phones and computer network capabilities were added to the new technical office building, allowing telecommunications with this space. Initial plans for a greenhouse renovation and Plant and Soil Processing Facility are being developed. This project's $1 million FY '97 construction budget has been postponed until FY '98 by the DOE funding delays. The Conference Center has continued to see wide use, both by the SREL and the local community. The facility was used to host a total of 166 scientific meetings and environmental education programs for students, teachers and the general public this past year.

In addition to the construction of research facilities, SREL has set up a 3,500 ft^2 building with four classrooms for Distance Learning. Within the Distance Learning Center (DLC) the hardware for two classrooms is operational and furniture for a third traditional classroom has been purchased. Distance learning is a technology that will allow faculty to meet and respond positively to the research and teaching needs of the Laboratory and DOE. This will enable programs effectively to reach large audiences. In addition, it will allow training of a workforce while that workforce is employed in the workplace. These classrooms can be connected into the Georgia Statewide Academic and Medical Systems (GSAMS) network. Since the DLC has been in operation, presentations by **Dr. Chris Romanek** on "The possibility of life on Mars" have been made to more than 15 public schools throughout Georgia. The DLC has been involved in training programs from Georgia's Training and Development Department, several conferences were held involving our students and faculty both here and on campus, and a course in Radioecology was presented by **Drs. Thomas G. Hinton**, **Charles Jagoe**, and **Ronald K. Chesser** of SREL and **Dr. Ward F. Whicker** from Colorado State University and several SREL faculty. Short-range goals of the SREL DLC include offering a Master's Degree in Environmental Toxicology from the University of Georgia, continuing outreach programs with the "Life on Mars" series, and expanding to other ecological topics. Georgia Tech is exploring the option of offering several programs through the SREL DLC, including graduate courses in electrical engineering, environmental engineering, health physics, industrial and systems engineering, and mechanical engineering. Negotiations are being conducted with Augusta State University to offer their MBA program

and with a consortium of Technical schools to offer their programs through our facility. In addition, the SREL is exploring a collaborative partnership with the National Science Center's Ft. Discovery in Augusta, GA.

SREL has developed two web pages, an Internet Homepage and an IntraNet Homepage for use by SREL staff. The Internet Homepage is at www.uga.edu/~srel and includes information about the current Laboratory research programs and a description of faculty and facilities. In addition, newspaper releases are available. The IntraNet Homepage is for administration purposes and will ultimately be a mechanism for communicating research findings to other organizations on the SRS.

The Savannah River Ecology Laboratory played a pivotal role in the development of the Environmental Centers of Excellence Program at the Savannah River Site. These centers include the National Water Research Center, the Soil Remediation Research Center, and the International Initiative in Radioecology. Membership in these centers includes the SREL and the ERDA and South Carolina SCUREF Universities. In response to a call for proposal from the Centers, SREL submitted 19 proposals of which seven were funded for a total three year award of $3,010,351. The funded projects are:

Physiochemical Controls Governing Solute Transport on the SRS: Implications to Environmental Remediation.
Principal Investigators: Paul M. Bertsch, John C. Seaman, and Christopher Romanek (SREL) and Richard N. Strom (WSRC)

Selective Colloid Mobilization (SCM): A Novel *in situ* Aquifer Remediation Technology
Principal Investigators: Paul M. Bertsch and John C. Seaman (SREL) and Richard N. Strom (WSRC)

Predicting the Fate of ^{137}Cesium in Ponds: Sensitivity and Uncertainty Analyses and Verification of a Model
Principal Investigators: Barbara E. Taylor, Philip M. Dixon, and Thomas G. Hinton (SREL) and Lars Hakanson (Uppsala University, Sweden)

An Experimental Approach to Constructed Treatment Wetland Design
Principal Investigators: Rebecca R. Sharitz, Beverly S. Collins, and J Vaun McArthur (SREL) and W. Harold Ornes (University of South Carolina, Aiken)

Enhanced Degradation of Halogenated Organic Contaminants Using Redox-Manipulated Aquifer Material and Iron-Bearing Clays
Principal Investigators: Gary L. Mills and Will P. Gates (SREL) and Valentine A. Nzengung (University of Georgia)

A Field Test of the Efficiency of a Biotic System for Remediating Radionuclide and Metal Contamination in Surface Waters
Principal Investigators: Thomas G. Hinton and John E Pinder, III

In addition to the Centers of Excellence funding, SREL researchers were awarded funding by the DOE Environmental Monitoring and Science Program. Thomas G. Hinton, Justin D. Congdon, Christopher Rowe and David E. Scott (SREL) with F. Ward Whicker and J. Bedford (Colorado State University)were funded $897,666 for their proposal titled Determining Significant Endpoints for Ecological Risk Analyses. This research examines the ecological significance of radioactive and heavy metal contamination and addresses a suite of ecological risk-related questions pertinent to the fields of toxicology, physiological ecology, radiation biology, population biology, radiation ecology, and risk analysis.

In addition to the funding received from the Department of Energy through its contract with the University of Georgia, SREL researchers also have received funding from other sources. This funding is in the form of both research grants and contract work. The funding provided by the 27 ongoing projects listed below, totals $3,010733 for the life of all the listed proposals.

Grants/Proposals

PI:	Dr. Domy Adriano
Project Title:	Distribution and Dynamics of Radionuclides in Ecosystems of the Savannah River Site
Funding Agency:	Education, Research and Development Association (ERDA)
Funding Level:	$92,689
PI:	Dr. Beverly Collins
Project Title:	Herbivory and Plant Interactions in Bottomland Hardwood Experimental Gaps
Funding Agency:	United State Department of Agriculture
Funding Level:	$142,875
PI:	Dr. Domy Adriano
Project Title:	Coal Ash Utilization for Soil Amendment to Enhance Water Relations and Turf Growth
Funding Agency:	Electric Power Research Institute
Funding Level:	$59,935
PI:	Dr. Paul Bertsch
Project Title:	Advanced Analytical Center for Environmental Sciences
Funding Agency:	Education, Research and Development Association
Level:	$1,700,000

PI:	Dr. Peg Mulvey
Project Title:	Determine the Status of the Carolina Heelsplitter Mussel in Eastern S.C. and Determine Presence of Related Indication Species of High-Integrity Stream Systems
Funding Agency:	South Carolina Department of Natural Resources
Funding Level:	$25,000

PI:	Dr. Peg Mulvey
Project Title:	Sequencing Studies of Gastropod Snails
Funding Agency:	Smithsonian Institution
Funding Level:	$7,485

PI:	Dr. Chris Romanek
Project Title:	Three-Oxygen Isotope Analysis at the Leal Lab, Johnson Space Center, National Aeronautics and Space Administration
Funding Agency:	Lockheed
Funding Level:	$24,640

PI:	Dr. I. Lehr Brisbin, Jr.
Project Title:	Prey Density and Diversity at Wood Stork Foraging Sites in Coastal Georgia
Funding Agency:	Georgia Department of Natural Resources
Funding Level:	$18,699

PI:	Dr. Whit Gibbons/Dr. Mike Dorcas
Project Title:	Testing and Evaluating the Automated Wildlife Surveyor
Funding Agency:	Idaho State University
Funding Level:	$6,000

PI:	Dr. Whit Gibbons/Dr. Gary Meffe
Project Title:	Ecological Risk Assessment
Funding Agency:	Consortium for Risk Evaluation with Stakeholder Participation Rutgers
Funding Level:	$33,000

PI:	Dr. I. Lehr Brisbin, Jr.
Project Title:	Inventory of Wading Bird Colonies in Georgia's Coastal Plain
Funding Agency:	Georgia Department of Natural Resources
Funding Level:	$27,880

PI: Dr. Whit Gibbons
Project Title: Ecology of Gopher Tortoises
Funding Source: South Carolina Department of Natural Resources
Funding Level: $5,000

PI: Dr. Whit Gibbons
Project Title: Landscape Level Research on the Little Pee Dee in South Carolina: Herpetofauna and Forest Management
Funding Source: International Paper Co.
Funding Level: $284,926

PI: Dr. Peg Mulvey
Project Title: Deep Phylogeny of Hydrobiid Gastropods
Funding Source: Smithsonian Institution
Funding Level: $18,200

PI: Dr. Paul Bertsch
Project Title: Impact of Stable Colloidal Suspensions in Soils and Geologic Materials
Funding Source: Westinghouse Savannah River Company
Funding Level: $43,387

PI: Dr. Rebecca Sharitz
Project Title: Wetland Database-Guided Field Verification Communities in the Congaree Swamp
Funding Source: United States Department of Interior, National Park Service
Funding Level: $33,000

PI: Dr. Barbara Taylor/Evelyn Gaiser
Project Title: Dissertation Research: Paleolinmnological Reconstruction of Holocene Environments in Wetland Ponds of the Upper Atlantic Coastal Plain
Funding Source: National Science Foundation
Funding Level: $5,750

PI: Dr. Paul Bertsch
Project Title: Environmental Impact of Stable Colloidal Suspensions in Soils and Geologic Materials
Funding Source: Education, Research and Development Association
Funding Level: $140,544

PI:	Dr. Sue Clark
Project Title:	Development of an Improved Assay for the Determination of Gross Alpha and Beta Concentrations in Soil
Funding Source:	Education, Research and Development Association
Funding Level:	$70,214

PI:	Dr. Sue Clark
Project Title:	Development of Improved Gross Alpha Techniques for Rapid Screening of Environmental Samples
Funding Source:	Oakridge Institute of Science and Education
Funding Level:	$49,996

PI:	Dr. Chris Romanek
Project Title:	Isotopic Analyses of Groundwater and Sediment Samples Associated with SRS Coal Storage Piles
Funding Source:	Westinghouse Savannah River Company
Funding Level:	$7,500

PI:	Dr. Beverly Collins
Project Title:	Baseline Survey of Ephemeral Understory Herbs of the WESTVACO Wildlife and Ecosystem Research Forest
Funding Source:	WESTVACO
Funding Level:	$3,306

PI:	Dr. I. Lehr Brisbin, Jr.
Project Title:	Aerial Censuses of the "LCP" Coastal Marsh Site for Wading Birds
Funding Source:	PTI Environmental Service
Funding Level:	$20,263

PI:	Dr. Chris Romanek
Project Title:	NASA/ASEE Summer Faculty Fellowship Award
Funding Source:	University of Houston
Funding Level:	$11,000

PI:	Dr. Whit Gibbons
Project Title:	Teacher Training in Ecology
Funding Source:	Donnelly Foundation
Funding Level:	$10,000

PI:	Dr. Sue Clark
Project Title:	Coupling Geochemistry and Transport Code in Support of Environmental Restoration Activities
Funding Source:	Westinghouse Savannah River Company
Funding Level:	$49,212

PI:	Dr. Chuck Jagoe
Project Title:	Determination of Mercury Concentrations in Wood Stork (*Mycleria americana*) Nestlings in Georgia
Funding Source:	Georgia Department of Natural Resources
Funding Level:	$20,000

PI:	Dr. Gary Mills
Project Title:	Bioremediation of Petroleum and Chlorinated Hydrocarbon Contaminated Soils: Analysis of Soil and Gases for Contaminant, Intermediates, Metabolic Inducers, and Gaseous Nutrients
Funding Source:	Westinghouse Savannah River Company
Funding Level:	$18,018

PI:	Dr. Mike Dorcas
Project Title:	Development and Testing of an Automated Recording System for Monitoring Anurans and Birds of the SRS
Funding Source:	Idaho State University
Funding Level:	$26,839

PI:	Dr. Justin Congdon/Rebecca Yeomans
Project Title:	Dissertation Improvement: Experimental Tests of the Parental Investment in Care Hypothesis
Funding Source:	National Science Foundation
Funding Level:	$5,375

PI:	Dr. Paul Bertsch/Dr. Doug Hunter
Project Title:	Metals Management in how Effluent Pulp and Paper Mills
Funding Source:	Georgia Consortium for Technological Competitiveness in Pulp and Paper
Funding Level:	$60,000

Awards, Honors, and Outstanding Recognition

Dr. Paul M. Bertsch was the recipient of the 1996 Marion L. and Christie M. Jackson Award for Research Excellence in Soil Chemistry and Mineralogy by the Soil Science Society of America.

Dr. I. Lehr Brisbin was the recipient of the Earle R. Greene Award for Outstanding Contributions to Ornithology from the Georgia Ornithology Society.

Dr. Michael C. Newman has been an invited participant in an Environmental Protection Agency (EPA) workshop series on ecotoxicology that is developing an updated conceptual framework and validated tools for use by the EPA.

Dr. Ronald K. Chesser was elected a member of Chernobyl Research Council.

Dr. Philip M. Dixon received the Distinguished Achievement Medal from the American Statistical Association, Section on Statistics and the Environment.

Dr. J. Whitfield Gibbons was appointed by President Knapp to a Committee on the Environmental Science Field Education Program at the Savannah River Site for Regional Historically Black Colleges and Universities.

Dr. Thomas G. Hinton was appointed by the board of directors for the National Council on Radiation Protection and Measurements (NCRP) to a new scientific committee on Cesium in the Environment. He was also invited to serve a two-year term as a member of the Citizens Advisory Board Committee on Public Health and Research Activities at Department of Energy Sites.

Dr. J Vaun McArthur was appointed to Brigham Young University's National Advisory Board.

Dr. John E. Pinder and **Allen Cook**, of TRW Systems Services Company, were awarded the John I. Davidson Award for Practical Papers by the American Society for Photogrammetry and Remote Sensing for their paper "Relative accuracy of rectifications using coordinates determined from maps and Global Positioning Systems." *Photogrammetric Engineering and Remote Sensing* 62:73-77.

Dr. Christopher S. Romanek, the newest faculty member at the SREL, recently was selected to Who's Who in America, was nominated for Thomas O. Paine Memorial Award, and received a NASA/AASE Certificate of Recognition as a result of a recently published article in *Science* providing evidence for the microfossil remains of past Martian biota. In addition,

he was *Popular Science* Magazine's Grand Award Winner "The Best of What's New," and *Time* Magazine's Runner-up "Man of the Year."

Dr. Christopher S. Romanek was an invited participant in "Biogeochemistry 2000," an international workshop to determine directions for future research in subsurface biogeochemistry. The workshop was held at the University of Reading, UK, in September 1996.

Dr. Rebecca R. Sharitz has been awarded the Meritorious Teaching Award from the Association of Southeastern Biologists (ASB). This was the second time in three years that an SREL senior researcher received the ASB Meritorious Teaching Award. Dr. J. Whitfield Gibbons received the award in 1995. Dr. Sharitz is a member of the National Research Council (NRC) Committee on Non-Economic and Economic Valuation of Biodiversity: Applications for Ecosystem Management. She is currently the secretary-general of INTECOL, the International Association for Ecology.

Graduate student **Adrienne L. Edwards** recently was presented the first Wilbur Duncan Award for her overall excellence as a graduate student in the UGA Botany Department. The review committee, in identifying the Outstanding Graduate Student," took into account the student's contribution to excellence in teaching, research, and service.

Graduate student **John R. Lee** was awarded second place in the Henri Siebert Outstanding Student Presentation Competition for his talk titled A Spatial ecology of cottonmouths (*Agkistrodon piscivorus*) in South Carolina: Activity ranges, movement rates, and overwintering sites" at the Society for the Study of Amphibians and Reptiles annual meeting in Lawrence, Kansas, July 1996. A second graduate student, Mark J. Komoroski, received honorable mention for his talk titled "Relationships of lipids to ovum size in the mole salamander, *Ambystoma talpoideum.*"

Graduate Student **Rebecca Yeomans** received a National Science Foundation (NSF) Dissertation Improvement Grant for her proposal titled "Experimental tests of the parental investment in care hypothesis in reptiles."

Four SREL graduate students received Sigma Xi Grant-in-Aid Research Awards:
Rebecca Yeomans, "Experimental reductions in yolk reserves in hatchling turtles: Is 'fitness' reduced?";
Adrienne Edwards, "Local adaptation along hydrologic gradients in freshwater wetlands";
Susan Miller, "Flooding and mycorrhizae: Variation in species composition of VA mycorrhizae along a hydrologic gradient"; and
Debra L. Wohl, "Actinomycete-fungal antagonism: The indirect effect on organic matter processing and the possible mechanisms involved."

PUBLICATIONS

Books Published and in Press

Adriano, D.C., Z.S. Chen and S.S. Yang (eds.) *Biogeochemistry of Trace Metals 2. Advances in Environmental Science, Science.* Reviews Ltd., London, UK (in press)

Iskander, I.K. and D.C. Adriano, (eds.) *Remediation of Metal-Contaminated Soils. Advances in Environmental Science, Science.* Reviews Ltd., London, UK (in press)

Leslie, M., G.K. Meffe, J.L. Hardesty and D.L. Adams. (eds.) 1996. *Conserving Biodiversity on Military Lands.* The Nature Conservancy, Arlington, VA.

Meffe, G.K. and C.R. Carrol. 1996. *Principles of Conservation Biology.* 2nd Edition. Sinauer Associates. Sunderland, MA.

Newman, M.C. and C.L. Strojan. (eds.) *Risk Assessment: Logic and Measurement.* Ann Arbor Press Inc., Chelsea, MI. (in press)

Newman, M.C. (ed). *Fundamentals of Ecotoxicology.* Ann Arbor Press Inc., Chelsea, MI. (in press)

Rhodes, O.E., R.K. Chesser and M.H. Smith. 1996. *Population Dynamics in Ecological Space and Time.* University of Chicago Press, Chicago, IL.

Journal Articles and Book Chapters Published

SREL
Reprint No.

2107 Kennett, R. 1996. Growth and maturity of two freshwater turtles, *Chelodina rugosa* and *Elseya dentata*, from the wet-dry tropics of Northern Australia. *Herpetologica* 52:383-395.

2108 Seaman, J.C., P.M. Bertsch, S.F. Korom, and W.P. Miller. 1996. Physicochemical controls on non-conservative anion migration in coarse-textured alluvial sediments. *Ground Water* 34:778-782.

2109 Jenssen, T.A., J.D. Congdon, R.U. Fischer, R. Estes, D. Kling, S. Edmands, and H. Berna. 1996. Behavioral, thermal, and metabolic characteristics of a wintering lizard (*Anolis carolinensis*) from South Carolina. *Functional Ecology* 10:201-209.

2110 Sugg, D.W., F.S. Dobson, R.K. Chesser, and J.F. Hoogland. 1996. Population genetics meets behavioral ecology. *Trends in Ecology and Evolution* 11:338-342.

2111 Simon, L., H.W. Martin, and D.C. Adriano. 1996. Chicory (*Cichorium intybus* L.) and dandelion (*Taraxacum officinale* web.) as phytoindicators of cadmium contaminators. *Water, Air and Soil Pollution* 91:351-362.

2112 Pickens, R.M., and C.H. Jagoe. 1996. Relationships between precipitation and surface water chemistry in three Carolina bays. *Archiv für Hydrobiologie* 137:187-209.

2113 Schultz, I.R., E. Peters, and M.C. Newman. 1996. Toxicokinetics and disposition of inorganic mercury and cadmium in channel catfish after intravascular administration. *Toxicology and Applied Pharmacology* 140:39-50.

2114 Kandl, K.L., and A.J. Thompson. 1996. Responses of eastern mosquitofish (*Gambusia holbrooki*) to acute salinity stress: Do family effects obscure inbreeding and genotypic effects? *Canadian Journal of Fisheries and Aquatic Sciences* 53:753-760.

2115 Crane, M., and M.C. Newman. 1996. Scientific method in environmental toxicology. *Environmental Reviews* 4:112-122.

2116 McCloskey, J., M.C. Newman, and S.B. Clark. 1996. Predicting the relative toxicity of metal ions using ion characteristics: Microtox bioluminesence assay. *Environmental Toxicology and Chemistry* 15:1730-1737.

2117 McArthur, J V., and K.K. Moorhead. 1996. Characterization of riparian species and stream detritus using multiple stable isotopes. *Oecologia* 107:232-238.

2118 Congdon, J.D., and J.W. Gibbons. 1996. Structure and dynamics of a turtle community over two decades. In *Long-Term Studies of Vertebrate Communities*, edited by M. Cody and J. Smallwood: Academic Press, Inc.

2119 Chlopecka, A. 1996. Assessment of form of Cd, Zn, and Pb in contaminated calcareous and gleyed soil in Southwest Poland. *The Science of the Total Environment* 188:253-262.

2120 Hartman, G.D. 1996. Genetic variation in a subterranean mammal, *Scalopus aquaticus* (Insectivora: Talpidae). *Biological Journal of the Linnean Society* 59:115-125.

2121 Semlitsch, R.D., D.E. Scott, Joseph H.K. Pechmann, and J.W. Gibbons. 1996. Structure and dynamics of an amphibian community: Evidence from a 16-year study

of a natural pond. In *Long-term Studies of Vertebrate Communities*, edited by M. L. Cody and J. Smallwood: Academic Press, Inc.

2122 Onken, B.M., and L.R. Hossner. 1996. Determination of arsenic species in soil solution under flooded conditions. *Soil Science Society of America Journal* 60:1385-1392.

2123 Sowder, A.G., S.B. Clark, and R.A. Fjeld. 1996. The effect of silica and phosphate on the transformation of schoepite to becquerelite and other uranyl phases. *Radiochimica Acta* 74:45-49.

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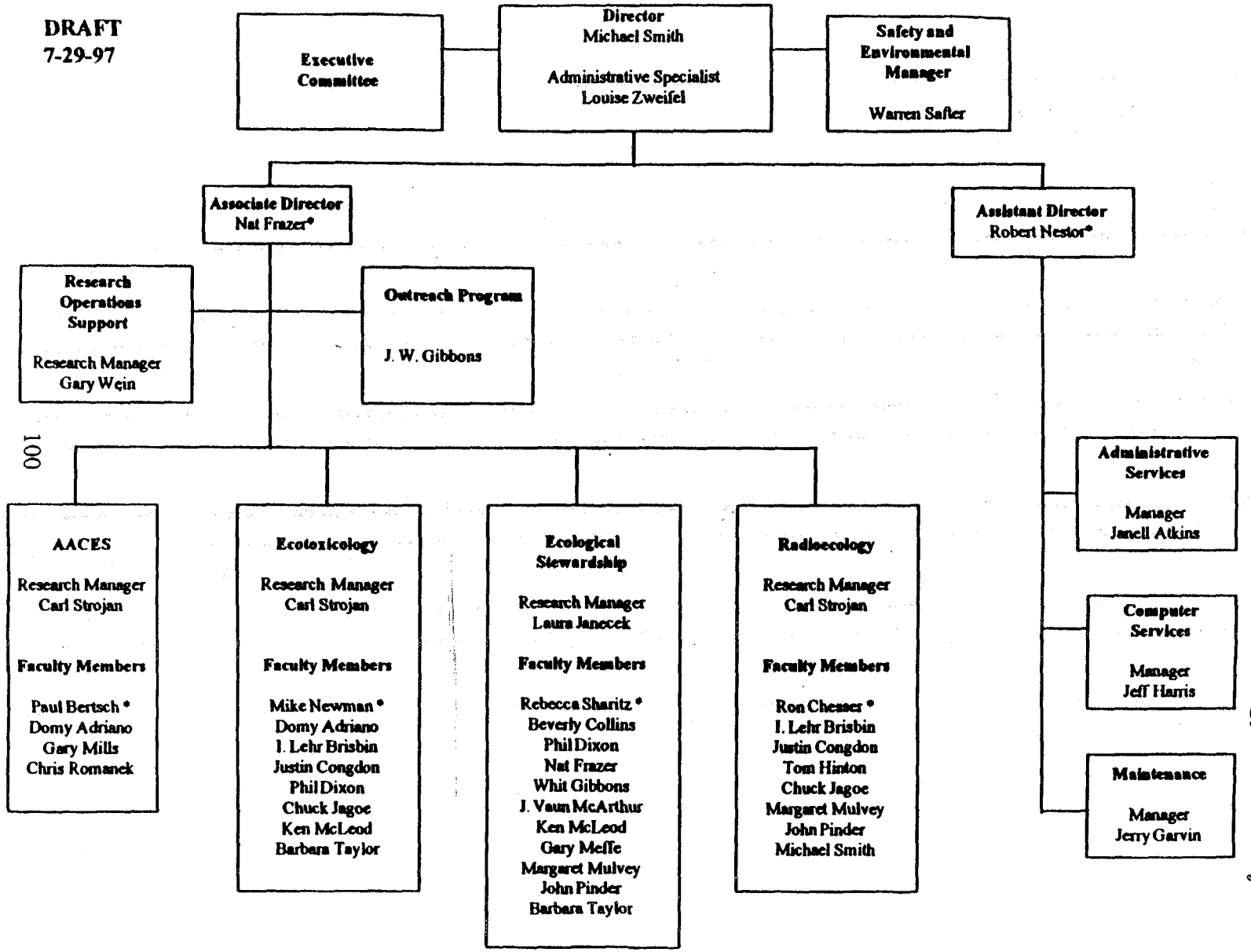
APPENDIX.

Figure 1. Organizational Chart, Savannah River Ecology Laboratory



* Denotes Group Representative to Executive Committee