**SAVANNAH RIVER ECOLOGY LABORATORY
ANNUAL TECHNICAL PROGRESS REPORT**

OF

ECOLOGICAL RESEARCH

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Michael H. Smith, Director

Prepared by:

Gwendolyn Johnson

Edited by:

Milda R. Vaitkus and Gary R. Wein

MASTER

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SUMMARY

The Savannah River Ecology Laboratory (SREL) completed another productive year of ecological research on the Savannah River Site (SRS). The following list represents some of the many scientific achievements and activities accomplished by SREL during the past year:

- Savannah River Ecology Laboratory faculty published two books this past year. The Savannah River Ecology Laboratory's faculty, technicians, students and visiting scientists published 100 journal articles and book chapters in the peer-reviewed literature. In addition, 76 journal articles and book chapters are in press. Faculty and staff also lectured or presented papers or posters at 154 seminars, universities, or professional meetings.
- Savannah River Ecology Laboratory formed a committee to develop a list of topics for a biannual or annual symposium series in environmental science. The first symposium was held May 3-6, 1993 in Aiken, South Carolina. The topic of this symposium, "Spatial and Temporal Aspects of Population Processes," attracted 48 national and international participants with 11 presentations.
- A strategic plan was developed for the laboratory with guidance from members of the University of Georgia's Department of Management.
- In SREL's education program, 67 undergraduate students, graduate students, and pre-college teachers conducted research at the laboratory. Four students received master's degrees, and four students received doctoral degrees in the past year. The Savannah River Ecology Laboratory also participated in a Young Scholar Program for high school seniors, with two students participating this summer.
- The Environmental Outreach and Education Division hosted about 45 tours of the field and the laboratory, gave 182 lectures to schools and civic groups, and participated in 10 exhibits.
- In the SREL Data Archive Program, the results of 65 studies were archived this year.
- The Savannah River Ecology Laboratory added new people to its staff this year. Dr. Thomas Hinton joined the faculty of the Division of Biogeochemical Ecology, Dr. Margaret Mulvey joined the faculty of the Division of Wildlife Ecology and Toxicology, and Dr. Beverly Collins joined the faculty and will be participating in the Biodiversity Program. Dr. Laura Janecek joined the staff as Research

Manager for the Division of Wildlife Ecology and Toxicology and Dr. Gary Wein joined the staff as Research Manager for the Division of Wetlands Ecology.

- Among facility improvements, SREL completed construction of a laboratory building for radioecological research at Par Pond. Construction of a new computer facility also was completed. An environmental assessment and archaeological survey for a conference/visitor center were completed this year, and architectural plans are being finalized.
- Two SREL faculty members, Drs. Sue Clark and Thomas Hinton, were selected by the National Academy of Sciences to be among ten American scientists to participate in a workshop on the Chernobyl Nuclear accident in the former Soviet Union.
- The Savannah River Ecology Laboratory received its first funding through the Education, Research and Development Association of Georgia Universities (ERDA). Dr. Sue Clark received one award to conduct research on contaminant geochemistry, and a second award will support research in radioecology by Dr. F. Ward Whicker.

I. OVERVIEW OF RESEARCH PROGRAMS AND PROGRAM COMPONENTS

A. ENVIRONMENTAL OPERATIONS SUPPORT

This field-oriented program emphasizes the use of research opportunities on the SRS while focusing on data information needs of the Department of Energy. Laboratory and special purpose facilities enhance this field-oriented approach. The Savannah River Ecology Laboratory has been gathering baseline information on the long-term aspects of the SRS environment since operations began in 1951. Research programs integrated with Westinghouse's environmental monitoring support the mission of the site and help maintain environmental quality at the SRS. Research in the various program components is summarized in the following sections.

A.1. SRS IMPACTED WETLANDS

Natural Succession in Fourmile Branch Delta

C. J. King, R. R. Sharitz, D. W. Imm, and K. W. McLeod

Since C-Reactor shut down in 1985, the Fourmile Branch corridor and delta have been revegetating through natural succession. In most disturbed habitats, secondary succession begins as seeds in the soil germinate and plants resprout from damaged rootstocks. Because the Fourmile Branch system was affected by thermal effluents from reactor operations for more than 30 years, the soil seed bank was eliminated, and the sprouting ability of the damaged vegetation was lost. Therefore, primary succession began in 1985 with the exposure of the bare sediments, which had been underwater for 30 years.

In 1987, permanent plots were established in the corridor and delta of Fourmile Branch to measure the rate and pattern of plant succession. The vegetation in these plots was sampled in 1987, 1989, and 1993. Early changes in species composition from 1987 to 1989 have been described in previous annual reports. These data are being combined with satellite imagery to assess the invasion of woody plant species in the Fourmile Branch delta system since reactor shutdown.

Multispectral scanner data collected in 1985, 1988, 1990, and 1993 are being rectified and classified using Geographic Information System (GIS) technology. Data from the field sampling are being summarized to determine the major types of woody plant associations and to assist in classifying the multispectral scanner data. The classified images are being analyzed to determine the locations and the amount of woody plant invasion, to detect patterns of change over time, and to identify sites where succession is occurring most rapidly. This research documents patterns and rates of natural succession in disturbed wetlands and may serve as a framework for evaluating the effectiveness of wetland restoration programs.

A.2. SRS STREAMS

Ecology of Savannah River Site Streams

J V. McArthur

During the past year, we have initiated studies to 1) determine gene exchange among native aquatic bacteria; 2) estimate plasmid diversity within a specific population of bacteria and within the whole bacterial assemblage along the Upper Three Runs Creek drainage; and 3) determine the role of bacteriophages in controlling bacterial populations and gene exchange among native aquatic bacteria. All of these studies are developed around the theoretical construct of information spiralling. We have been able to show for the first time that plasmids carrying genes for mercury resistance and/or antibiotic resistance are transferred from natural donors. This observation is important, as many microbial functions may be similarly transferred. Any process that inhibits or enhances these exchange rates will ultimately affect ecosystem function. The work with the bacteriophage, if successful, will be another first: a demonstration of the coupling of two separate evolutionary mechanisms. This not only has immediate value to science, but also to the understanding way stream ecosystems function. Our ultimate goal continues to be relating bacterial genetic processes to ecosystem functions.

Recent Publications: SRS Streams

- Floyd, M. A., J. C. Morse, and J V. McArthur. 1993. Aquatic insects of Upper Three Runs Creek, Savannah River Site, South Carolina. Part IV: Caddisflies (Trichoptera) of the lower reaches. *J. Entomol. Sci.* 28:85-95.
- Leff, L. G., J V. McArthur, and L. J. Shimkets. 1992. Information spiraling: Movement of bacteria and their genes in streams. *Microb. Ecol.* 24:11-24.
- Leff, L. G., J V. McArthur, and L. J. Shimkets. 1993. Evaluation of sources of bacteria in coastal plain streams using gram staining. *Arch. Hydrobiol.* 126:461-468
- McArthur, J V., L. G. Leff, and M. H. Smith. 1992. Genetic diversity of bacteria along a stream continuum. *J. N. Am. Benthol. Soc.* 11:269-277

A.3. TRACE ORGANIC COMPOUNDS

Interactions of Natural Organic Matter and Contaminant Organic Compounds

G. L. Mills

Lipids are one of the major classes of naturally occurring organic molecules, and certain lipid groups are among the most hydrophobic of these biologically generated compounds. Consequently, lipids play a particularly important role in the partitioning of hydrophobic organic contaminants. Thus, understanding the distribution and qualitative composition of lipids within the environment will be useful in predicting the transport of contaminants. The lipid composition of solvent extracts was determined in forest soil profiles collected along a transect across a hillslope toposequence in the Upper Three Runs Creek watershed. Extracts were separated into hydrocarbon, fatty acid, alcohol, and sterol fractions using silica gel chromatography before analysis by gas chromatography and gas chromatography-mass spectroscopy. The composition of these major lipid classes was compared within a soil profile, across the hillslope gradient, and with leaf litter in various stages of decomposition, to evaluate the dynamics of this important fraction of the hydrophobic component of soil organic matter.

Lipid concentrations of all the fractions examined were highest in the surface horizons and decreased with depth. However, lipid components were identified even in the deeper horizons within the subsoil. In the surface horizons the primary source of soil lipid material is leaf litter decomposition. Lipids in the subsoil are probably derived from multiple sources. Although some of these compounds originate from microbial production, a portion is derived from the remains of the waxy cuticle of leaf detritus. This was ascertained using specific lipids that serve as molecular markers for a particular source.

The presence of these cuticular lipids in the subsoil is of particular interest because these compounds have a very low water solubility. One mechanism by which they may be transported from the surface horizons to the subsoil is by association with colloidal micelles. One would expect that lipid colloids also would serve as a mechanism for the facilitated transport of hydrophobic organic contaminants. We have recently examined this hypothesis by determining the lipid composition of water-soluble carbon extracts of the surface horizons and comparing this lipid assemblage with that present in the subsoil. The results indicate an enrichment of cuticular fatty acids exist in the water-soluble organic carbon extracted from the surface horizon, thus supporting our hypothesis. Although these mobile lipids may facilitate movement of contaminants from the surface horizon, their role in the subsoil may be quite different. Other workers have suggested that mineral and oxide phases may be the predominate sorting materials in low carbon environments. However, the waxy cuticular lipids have a higher partitioning coefficient than the bulk carbon value used in these calculations and thus, may compensate for the lower carbon content. We are conducting studies to evaluate this hypothesis.

Recent Publications: Trace Organic Compounds

Mills, G. L. Adsorption of tetraphenylboron and diphenylboric acid in soil. *Environ. Tox. Chem.* (In Press).

Novak, J. M., G. L. Mills, and P. M. Bertsch. 1992. Estimating the percent aromatic carbon in soil and aquatic humic substances using ultraviolet absorbance spectroscopy. *J. Environ. Qual.* 21:144-147.

Novak, J. M., P. M. Bertsch, and G. L. Mills. 1992. Carbon-13 nuclear magnetic resonance spectra of soil water-soluble organic carbon. *J. Environ. Qual.* 21:537-539.

A.4. RADIOECOLOGY

Radioecological Studies of the Par Pond System

F. W. Whicker and T. G. Hinton

Emphasis this year was placed on examining the impacts of the 5.8 m drawdown of Par Pond. The drawdown decreased the surface area of the pond by 50% and exposed about 525 ha of contaminated sediments, resulting in the site being declared a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) operable unit. Samples of exposed and underwater sediments, water, vegetation, and aquatic animals were taken on a routine basis. Two of the more striking impacts seen to date are related to the physical and chemical changes incurred as a result of the drawdown. Physical destruction of the macrophyte beds reduced the cover for small prey fish, resulting in a temporary increase in food availability and body condition in largemouth bass. This was later followed by a period of declining body condition of the bass. Significant re-establishment of the aquatic vegetation occurred within a year following the drawdown. The primary chemical alteration was a three-fold decrease in the nutrient content of the water when accumulated ions were siphoned to Lower Three Runs Creek. Inputs of nutrient-rich Savannah River water declined, and groundwater began to dominate the system. Interestingly, ^{137}Cs levels in bass increased as nutrient levels in the water declined, demonstrating the classic radioecology paradigm that as concentrations of a stable chemical analog (potassium) decrease, the bioavailability of the analogous radioisotope (cesium) increases.

Substantial time and effort were spent preparing the new Radioecology Laboratory at Par Pond. When installation and calibration of the radionuclide counting equipment is complete, the ability to process environmental samples for radiological analysis is expected to increase about 30-fold.

Dr. F. Ward Whicker was honored as an Eminent Scholar in radioecology by the Education, Research and Development Association of Georgia Universities. Dr. Whicker is jointly funded by the Westinghouse Savannah River Company, SREL, and Colorado State University.

A faculty radioecologist, Dr. Thomas G. Hinton, was hired in October. Dr. Hinton has a joint appointment between the University of Georgia and the Paul Scherrer Institute in Switzerland. This arrangement allows Dr. Hinton to pursue international collaboration and maintain radioecological research funded by the Commission of European Communities. His current research topics deal with the resuspension of contaminated soil, which he conducts in the vicinity of Chernobyl, as well as on the Par Pond CERCLA unit. Dr. Hinton was recently selected by the National Academy of Sciences' Young Investigators Program to work on Chernobyl-related problems.

Radionuclide Environmental Chemistry

S. B. Clark

Knowledge of geochemical mechanisms controlling transport of radionuclides in environmental systems is essential for estimation of potential risks to human populations and cost-effective remediation of radioactively contaminated sites. Three approaches are being used to study these problems. First, we are working to develop simplified, low-level detection methods for radioisotopes in environmental samples. Second, we are using these methods to determine inventories of various isotopes in the different biogeochemical components of

environmental systems. Finally, we are studying radionuclide speciation and the kinetics of various geochemical processes to determine the chemical mechanisms controlling radionuclide transport.

Technical progress has been made toward all three research goals in this program. This year we have made significant progress in developing an improved method to determine $^{89,90}\text{Sr}$ in environmental samples. We are using solid phase extraction to isolate $^{89,90}\text{Sr}$ from soil and animal tissue collected from Par Pond. This technique complements our methods for determining transuranic levels in the same samples. We also plan to use these methods on samples collected from the Chernobyl area to study the effect of variations in sample matrices on chemical yields.

Speciation studies have continued for hazardous metals and radionuclides in typical SRS wasteforms and environmental systems. Studies on the speciation of Cr and Tc in cement wasteforms such as saltstone, indicate that Cr is chemically reduced in-situ to a less soluble and less toxic form. Although small- and large-scale leaching studies indicated that Tc also is less leachable in these matrices, X-ray absorption studies indicate that its reduced solubility is not the result of changes in its redox chemistry. While its exact speciation is not known, these results indicate that additional research is necessary to understand the geochemistry of cement-based wasteforms.

Uranium speciation has been the focus of another aspect of our work. The speciation of uranium waste generated in the SRS Naval Fuels process is largely unknown. However, this material has been disposed of in the solid radioactive waste burial ground on-site. Predicting the impact of disposal requires an understanding of the geochemistry of uranium under these conditions. Studies indicate that these wastes contain large quantities of polymeric uranium species. Uranyl dimers and trimers have been identified using 0-17 Nuclear Magnetic Resonance (NMR) and Extended X-Ray Absorption Fine Structure (EXAFS) techniques. These species likely will be more mobile than simple uranyl ions, and transport studies with these species are being planned.

Other future plans include the development of a laser photoacoustic facility. This will allow speciation experiments to be completed at lower concentrations than is possible now. In addition, kinetic studies are planned to study the rates of geochemical processes under environmentally relevant conditions. An understanding of these rates will provide information concerning the dominant processes occurring in the ecosystem.

Recent Publications: Radioecology

- Bajt S., S. B. Clark, S. R. Sutton, M. L. Rivers, and J. V. Smith. 1993. Synchrotron X-ray microprobe determination of chromate content using X-ray absorption near-edge structure. *Anal. Chem.* 65:1800-1804.
- Whicker, F. W., D. J. Niquette, and T. G. Hinton. 1993. To remediate or not: A case history. Pages 473-485 in *Proceedings of the 26th Midyear Topical Meeting of the Health Physics Society*, Coeur d'Alene, Idaho.

A.5. DATABASE SYNTHESIS

Research Data Archive Activities

R. K. Chesser and J. Heuer

The Data Synthesis program is motivated by the understanding that much of the data collected by scientists associated with the SREL has intrinsic value for this and future generations. Many of the studies represent measurements of phenomena in a unique space and time and thus cannot be duplicated if lost. Recent emphasis on long-term climatic changes suggests that historical data may become more valuable in the future than when initially collected. In response to these considerations, more than 145 studies encompassing nearly 600 data files have been included in a computer-based research data archive. These data files are stored in a readily accessible computer format on a high volume read/write optical disk system attached to the central computing facility. This system features excellent data security and is included in detailed backup procedures that are designed to nearly eliminate the chance of accidental loss of data. The data archive process has been administratively linked to the publication of peer-reviewed articles at the Laboratory. This serves to quickly identify candidate data sets for inclusion in the archive. Work is under way to provide an enhanced cross-referencing function between the Data Archive and Lab-sponsored manuscripts and articles. Work is also under way to transfer the operation of the Data Archive application to a Novell network server that will enhance accessibility of the system and make its operation more intuitive.

STUDIES INCLUDED IN THE SREL DATA ARCHIVE SYSTEM

This is a cumulative listing of SREL Data Archives. Asterisks (*) refer to studies included since June 30, 1992.

Abbreviated Study Title	Principal Investigator	Contact Person
Long term availability of Pu and Cm by crop plants as affected by soil type and amendments, a greenhouse study	Adriano	Ciravolo
U content of major regional agricultural crops when grown near separations facilities	McLeod	McLeod
Uptake of Cesium-137 by agricultural crops ("NRC-2")	McLeod	McLeod
Uptake of transuranics by tobacco plants - greenhouse and field study ("NRC-3")	McLeod	McLeod
Spatial and temporal movement patterns of Florida harvester ant (<i>Pogonomyrmex badius</i>) colonies on the SRS	Gentry	Smith
Geochemistry and bioaccumulation of trace elements from the D-Area ashbasins	N/A	Newman
Bachman's sparrow project	Pulliam	McCort
Microbial colonization of caddisfly cases	McArthur	McArthur
Age and growth of bluegill in Par Pond and Russell Reservoir, 1987-1990	Belk	Smith
"Common-garden" experiments using bluegills from Par Pond, a hatchery and a cross	Belk	Smith
Reproduction and lipid cycling in bluegill	Fischer	Fischer
Comparison of age and growth of bluegill and largemouth bass in Par Pond and Pond B in 1991	Belk	Smith
Effectiveness of the biobarrier to prevent root intrusions into buried hazardous waste	Dosskey	Adriano
Genotype data for Wood Storks, White Ibis, Great Egret, Tricolored Heron and Snail Kites	Stangel	Stangel
Spatial and size distribution of bottomland hardwood species along a gradient from Upper Three Runs Creek to the Savannah River Swamp	Dixon	Sharitz
Effects of fertilizer on the growth of bottomland hardwood tree species	McLeod	McLeod
The role of soil seedbanks in bottomland hardwood regeneration	Schneider	Sharitz
Effects of shade on the growth of swamp-bottomland tree seedlings	McLeod	McLeod
Effect of shade and moisture regime on seedling growth of ten bottomland tree species	McLeod	Ciravolo
Effects of boron on growth of bald cypress and water tupelo	Ciravolo	Ciravolo
Effects of experimental manipulations of population size on genetic variation and population growth of <i>Gambusia</i>	Leberg	Leberg
Surficial geology of three Carolina bays	Oliver	Pinder
A regional survey of the water chemistry of Carolina bays	Newman	Newman
Water quality measurements in Par Pond, Savannah River, Beaver Dam, Pen Branch, Fourmile, Upper Three Runs, Lower Three Runs, and Steel Creek	Newman	Newman
Distribution, filtration rates of native and introduced bivalves in Meyers Branch	McArthur	McArthur
Effects of SRS operations on distribution, abundance, and demographics of stream fishes	Aho	McCort
Embryo development and energy utilization in cottonmouth snakes	Fischer	Fischer
Determination of deer fetal age by measurement of eye lens weight	Rhodes	Novak
The relationship of radiocesium and potassium in the nutritional ecology of white-tailed deer on the SRS	Haselow	Brisbin
Ovarian analysis of white-tailed deer on the SRS	Rhodes	Chesser
Long-term population studies of white-tailed deer on the SRS, including demographic and genetic data	Novak	Smith
Distribution of <i>Nyssa aquatica</i> (water tupelo) in relation to water depth	Shea	Sharitz
Relationship of lipid cycles and reproduction in dusky shiner	Schultz	Congdon
Water quality of streams draining the DWPF site before, during and after construction	Knox	Chazal
Herpetofaunal diversity as determined by flat fencing techniques	Grant	Grant
Frequency, magnitude, and composition of fish kills occurring in SRS reactor cooling ponds	N/A	McCort
Influence of habitat structure on SRS stream fish assemblage composition	Meffe	Meffe
Fate of metals (Cd, Tl, V, Cr and Ni) applied under field conditions to two soil types, Blanton and Orangeburg	Kaplan	Adriano

Abbreviated Study Title	Principal Investigator	Contact Person
Plant succession in Four Mile Delta	Landaal	Sharitz
Study of plant composition and succession in Four Mile Delta	Landaal	Sharitz
Movement patterns of fish into a small headwater stream on the SRS	Aho	McCort
Fish reinvasion of Fourmile and Pen Branch following reactor shutdown	Aho	McCort
Ellington Bay <i>Gambusia</i> genetics data	Smith	Smith
Effects of bass predation on mosquitofish population structure	Lydeard	Leberg
Experimental examination of <i>Gambusia</i> dispersal	Leberg	Leberg
Genetic and demographic data for fish collected from 4 locations in Par Pond and one location in Pond C	N/A	Novak
Genetics of mosquitofish from thermally impacted stream habitats on the SRS	N/A	Novak
Allozyme genotype and time to death of <i>Gambusia holbrooki</i> during acute inorganic mercury exposure: Temporal stability	Mulvey	Newman
Allozyme genotype of mosquitofish, <i>Gambusia holbrooki</i> , during mercury exposure: Field verification	Heagler	Newman
Glycolysis and Krebs cycle metabolites in mosquitofish (<i>Gambusia holbrooki</i>) exposed to mercuric chloride I. Starvation and sex effects, II. Allozyme genotype effects	Kramer	Newman
Molecular and demographic characterization of hybridization in natural and experimental populations of <i>Gambusia</i>	Scribner	Smith
Interaction between mosquitofish and least killifish under experimental conditions	Lydeard	Lydeard
Respiration rates of mosquitofish at four temperatures	Heagler	Smith
Offspring size variation in eastern mosquitofish from contrasting thermal environments	Meffe	Meffe
Inhibition of GPI-2 allozymes by inorganic mercury: An in vitro study of GPI-2 isolated from <i>Gambusia holbrooki</i> , eastern mosquitofish	Kramer	Newman
Determination of GPI-2 Kinetic parameters and the effect of Hg on these parameters: Differences between GPI-2 and GPI-2 33 allozymes	Kramer	Newman
Hydrocory in swamps	Schneider	Sharitz
Steel Creek hydrocory	Schneider	Sharitz
Genetic correlates of fitness in the green treefrog, <i>Hyla cinerea</i>	McAlpine	Smith
<i>Hyla</i> hybrid population study	Lamb	Lamb
Genetic characteristics of several alpine ibex populations	Scribner	Smith
Factors affecting decomposition of leaf litter in blackwater streams on the SRS	McArthur	McArthur
Hydroxylamine batch extractions of seven different L-Lake sediments	Bertsch	Bertsch
Bacterial secondary production on vascular plant detritus in L-Lake, a cooling water reservoir on the SRS	Hodson	Strojan
Release of iron and manganese from L-Lake sediments as a function of time, redox potential, and temperature	Bertsch	Bertsch
L-Lake seed bank composition	Stanford	Sharitz
Iron and manganese flux from intact L-Lake sediment cores as a function of redox potential	Bertsch	Bertsch
Metal and radionuclide concentrations in L-Lake sediments prior to inundation	Bertsch	Strojan
Sequential extraction of L-Lake sediments for iron and manganese	Bertsch	Bertsch
Effect of fish predation on macroinvertebrates of L-Lake as influenced by the establishment of aquatic plants	Richardson	Taylor
Wetland vegetation establishment in L-Lake	Kroeger	Moorhead
Concentrations of uranium and other heavy metals in soils and sediments from M-Area sites (including Lost Lake)	Bertsch	Bertsch
Species numbers and demographic data for mammals collected from a southeastern hardwood forest	Gentry	Smith

Abbreviated Study Title	Principal Investigator	Contact Person
Cesium radionuclide uptake in mallard ducks held on Pond B	George Rhodes	Brisbin Chesser
Genetic structure, heterozygosity and energetic patterns in wintering mallard populations on the Southern High Plains of Texas	Smith	Smith
Comparison of oldfield mouse pelage coloration and soil coloration - a reanalysis of data collected by M. Smith during 1967-69	N/A	Smith
Genetic characteristics of Colorado mule deer collected from four locations	Lovich	Gibbons
Herpetological museum specimen database	Sharitz	Sharitz
Floral diversity at the site of the proposed New Production Reactor at SRS	McArthur	McArthur
Effects of stream nutrients on bacterial growth	James	James
<i>Nyssa</i> seedling growth and development in the HWCTR shadehouse and at Box Landing, Upper Three Runs Creek	Aho	McCort
Parasites of Bowfin (<i>Amia clava</i>) from the central Savannah River area	Longhi	McCort
Mercury retention in largemouth bass from Par Pond Reservoir, SRS, SC.	Savereno	Brisbin
Review of feral swine population on the SRS including an examination of demographic information from specimens collected from public hunts and trapping programs	Brisbin	Brisbin
Comparison of morphological characteristics between feral swine from SRS and Ossabaw Island, Chatham Co., GA.	Pinder	Pinder
Actinide elements in the water column of Pond B	McCreedy	Brisbin
Cesium 137 uptake by Pond B yellow bullhead	Lamb	Lamb
Pond B turtle flow cytometry study	Kelley	Pinder
Biomass dynamics and Cesium 137 cycling in floating-leaved macrophytes in a nuclear-contaminated aquatic ecosystem	McCreedy	Brisbin
Radioisotopes in aquatic turtles from Pond B	N/A	Sharitz
Emergent vegetation of Par Pond and Pond B	Taylor	Taylor
Food habits of selected species of fish in Pond C, a thermally stressed reservoir	Taylor	Taylor
Population densities of zooplankton in Pond C	Fischer	Fischer
Parental investment in alligator snapping turtles	Fischer	Fischer
Parental investment in western pond turtles	Adriano	Ciravolo
Four varieties of rice grown in the greenhouse in pots containing slightly contaminated soil	Adriano	Ciravolo
Rice grown in the greenhouse in flooded and nonflooded conditions	Alberts	Ciravolo
Uptake of Pu and gamma emitters by root crops grown at H-area and the effects of washing treatments on contamination removal	Adriano	Ciravolo
Transuranic uptake by tuber crops grown in a greenhouse in pots containing Four Mile Delta soil	Taylor	Taylor
Diet of larval salamanders from Rainbow Bay, a Carolina bay on the SRS	Taylor	Taylor
Zooplankton population dynamics in Rainbow Bay, a Carolina bay on the SRS, from 1984-1985	Pechmann	Pechmann
Amphibian and reptile populations near a Carolina bay on the SRS	Landaal	Sharitz
Population ecology of a rare and a common species of <i>Rhexia</i>	Megonigal	Sharitz
Effects of flooding on carbon allocation in bald cypress	Kennamer	Kennamer
Winter banding and body condition of ring-necked ducks on the SRS	N/A	Congdon
Ecology of reptile, amphibians and small mammals in the sandhill set-aside area	James	Sharitz
Identification of mature bottomland hardwoods in the southern South Carolina Coastal Plain (Savannah, Edisto, Salkehatchie, and Coosawhatchie Rivers)	Aho	Aho
Distribution of larval fish and fish eggs in Steel Creek Delta during Feb-Aug 1984	Aho	McCort
Distribution and abundance of ichthyoplankton across the SRS Swamp System	Aho	McCort
Distribution and abundance of ichthyoplankton in Steel Creek Delta - 1986 and 1987 collections	James	Sharitz
Seedling demography of <i>Nyssa</i> and <i>Taxodium</i> and other species at Box Landing, Upper Three Runs Creek, GAP, and Stave Swamp in the Savannah River Swamp		

Abbreviated Study Title	Principal Investigator	Contact Person
Effect of fly ash on the growth of water tupelo and cypress seedlings	Ciravolo	Ciravolo
Effect of fly ash on growth of selected swamp tree species	Ciravolo	Ciravolo
Maintenance of genetic polymorphism in inbred laboratory stock of a snail, <i>Biomphalaria glabrata</i>	Mulvey	Mulvey
Effects of irrigation and fertilization on photosynthesis and water use efficiency of turkey and laurel oaks in a sandhills community	McLeod	McLeod
Genetic diversity of soil bacteria along an environmental gradient	McArthur	McArthur
Effects of trenching on soil water chemistry along a general soil moisture gradient	Kovacic	Ciravolo
Bioaccumulation of radioactive Cesium (Cs) in plants collected from Steel Creek	Smith	Smith
Effect of stable isotope ratios on clam growth	McArthur	McArthur
Genetic diversity of bacteria along a stream gradient	McArthur	McArthur
Effect of interspecific competition on survival, growth, and lipid content of bluegill	Belk	Smith
Savannah River swamp fish population studies	Aho	McCort
Hydrology of Thunder Bay	Lide	Pinder
Movement of fishes into Pen Branch following reactor shutdown	Aho	McCort
The influence of topography on the nature of humic substances in soil organic matter at a site in the Upper Three Run Creek watershed	Novak	Bertsch
The influence of topography on the nature of humic substances in soil organic matter at a site in the Atlantic Coastal Plain of South Carolina (Upper Three Runs watershed)	Novak	Bertsch
Comparative analysis of three methods of tree mapping	Kramer	Cook
Long-term life history study of aquatic turtles of the SRS	N/A	Greene
Production and viability of tupelo seed: variability among trees	Shea	Shea
Effects of human activities on genetic variation of wild turkeys	Leberg	Leberg
Total body electrical conductivity as a means of measuring lipid levels in turtles	Zani	Congdon
Concentration of Cesium 137 from eggs of wood ducks captured on the SRS	Kenamer	Brisbin
Nesting biology of wood ducks on the SRS	Kenamer	Kenamer
Population genetics and morphology of the Red-Cockaded Woodpecker	Stangel	Stangel
Breeding biology and foraging ecology of Wood Storks of the Birdsville Colony and Savannah River Swamp System	Coulter	Brisbin
Aerial survey of waterfowl at various locations on the SRS	Kenamer	Kenamer
Winter banding study of waterfowl from the SRS	Kenamer	Brisbin
Comparison of productivity of bottomland hardwood forests in LA and SRS (SC)	Conner	Sharitz
*Hg in dusky shiners	Newman	Jagoe
*Toxicity of uranium on mosquitofish		Keklak
*Flood tolerance of seeds of selected species	Schupp	Schupp
*Hydrologic cycle and tree growth	Keeland	Keeland
*Bluegill age and growth study	Belk	Belk
*Bluegill "common-garden" growth study	Belk	Belk
*Fire ant life history	McAloney	McAloney
*Flying squirrel life history	Brady	Brady
*Bluegill/bass age and growth study	Belk	Belk
*Genetics of SE white-tail deer	Hilsteadt	Ratnaswamy
*Old field mouse pelage study	Smith	Belk
*Genetics of mountain millipeds	Mulvey	Edgar
*Interaction between poeciliids	Belk	Belk
*Turtle lipid study	Congdon	Zani
*Bachman's sparrow study (addition)	Dunning	Clements
*Vegetation dynamics in Carolina bays	Kirkman	Kirkman

Abbreviated Study Title	Principal Investigator	Contact Person
*Four Mile vegetation survey - 1981	Sharitz	King
*Root injury study	McLeod	Ciravolo
*1984 Greenhouse study	McLeod	Ciravolo
*1984 HWCTR study	McLeod	Ciravolo
*L-Lake study (addition of zooplankton data)	Taylor	DeBiase
*Understory vine study	Collins	Collins
*Uptake of Cs137 by Par Pond deer	Briabin	Benner
*Tomato study	Martin	Martin
*Effects of interspecific competition on bluegill	Belk	Belk
*Photochemical degradation of tetraphenyl B	Mills	Mills
*Uptake of Cs137 by Par Pond swine	Briabin	Benner
*Par Pond garden plot study	Whicker	Seel
*Uptake of Cs137 by Par Pond aquatic ecosystem	Whicker	Niquette
*Dandelion study	Adriano	Martin
*Uptake of Cs137 by Par Pond rabbits	Briabin	Benner
*Uptake of Cs137 by Pond B catfish (addition)	Briabin	Benner
*Subsurface coal contamination study	Strojan	Carlson
*Movement of wild turkeys on SREL	Briabin	Benner
*Wood stork study (addition)	Briabin	Bryan
*Effect of coal contaminants on trees	Strojan	Carlson
*Flat fencing study	Gibbons	Lynch
*Effect of petro chemical contaminants on amphibian reproduction	Gibbons	Gibbons
*Ellenton Bay snake study	Gibbons	Lynch
*Genetics of wild turkeys	Buford	Rhodes
*DWPF water quality study	Pechman	Chazal
*Largemouth bass genotoxicity study	Cheaser	Novak
*Cs137 uptake by wood duck	Briabin	Cowell
*Annual lipid cycle of mosquitofish	Meffe	Meffe
*Snapping turtles and ant mounds	Congdon	Berke
*Cannibalism in mosquitofish	Meffe	Meffe
*Water-finding orientation in turtles	Yeoman	Yeoman
*Life history of <i>Etheostoma fricksium</i>	Meffe	Layman
*Tupelo study	McLeod	Ciravolo
*Radionuclide contamination of bahia grass	Pinder	Pinder
*Pond B sedimentation flux study	Pinder	Pinder
*Larval growth of salamanders	Scott	Scott
*Evolution of sexual dimorphism in size	Sugg	Sugg
*SREL anole study	Congdon	Jenssen
*Borrow pit study	Adriano	Martin
*Salt toxicity of mosquitofish	Newman	Keklak
*Mosquitofish respiration study	Smith	Haegler
*Miscellaneous Par Pond bass studies (17 input from hardcopy)	Gibbons	Greene
*Cemophora growth study	Briabin	Briabin
*Feral pig and deer study	Briabin	Briabin
*Alligator aerial survey data	Briabin	Brandt
*Alligator feeding and growth study	Briabin	Seel
*SREL long-term deer population study (addition)	Smith	Novak
*Radionuclide uptake by pine	McLeod	Ciravolo
*Radionuclide contaminants of litter	McLeod	Ciravolo

A.6. WILDLIFE STUDIES

Waterfowl Research on the SRS

R. A. Kennamer and I. L. Brisbin, Jr.

Annual aerial surveys of SRS wintering waterfowl were completed in March 1993 and provided a continued evaluation of the effects of the Par Pond drawdown on these birds. Comparisons between the two years since the drawdown reservoir aerial survey data indicate that the number of waterfowl wintering on SRS reservoirs increased during the winter of 1992-93. This was suspected to be largely attributable to the re-establishment of aquatic plant communities and invertebrate prey species in Par Pond.

During November and December of 1992, 778 previously unbanded ring-necked ducks and 41 previously unbanded lesser scaup were captured, banded, and released at Par Pond and L-Lake. Since 1985, 3,870 ring-necked ducks have been banded and released at the site. An evaluation was made of hunter recoveries of ring-necked ducks banded on these reservoirs from 1985 to 1991. One hundred sixty-one hunter recoveries of these birds had been reported to the U.S. Fish and Wildlife Service (USFWS) Bird-Banding Laboratory as of mid-1992, and these occurred in 12 states and three Canadian Provinces. Average distance traveled from the reservoirs before being harvested was 102 ± 21 (SE) km for direct (same winter) recoveries ($n = 55$). These only occurred in three southeastern states (South Carolina, Georgia, and Florida). Elapsed time between banding on the reservoirs and harvest for direct recoveries averaged 23 days (range=1-47 days).

The 1993 wood duck breeding census has not been completed as of June 17, 1993, but a preliminary summary has been prepared. The 1993 nesting season is among the longest recorded on the SRS and, thus far, has resulted in the initiation of 191 nests that contained 2,883 eggs. Females have been captured and identified at 134 nests; these data will be used later this year to estimate population parameters for female wood ducks nesting in SRS boxes. Eighty-eight nests have been successful and produced a total of 1,041 ducklings. Nest abandonments thus far have amounted to 59 nests, and predation occurred in 13 nests. Par Pond nest box use during 1992 was not determined until early 1993 and was then compared to pre-drawdown use. Before drawdown, wood ducks used 49 (51%) of the Fourmile Branch nest boxes. Successful nests occurred in 39 (40.6%) of the boxes, and hatching success in successful nests averaged 76.0%. In 1992, following drawdown, nest box use was reduced to 39 (40.6%); 30 nests (31.3%) were successful and hatching success was 72%.

During a seven-year study of incubation mass dynamics of SRS nesting wood ducks, 1,215 body masses were recorded from 333 different females incubating first nests. One-way analysis of variance indicated that body mass, grouped into six-day intervals during an average 32-day incubation period, differed by interval, with day one to six body masses being greatest ($x = 581.1 \pm 2.2$ (SE) g) and those from day 25 and over being the least ($x = 559.6 \pm 2.2$ (SE) g). Larger females tended to nest earlier, and slopes from regressions of nesting date on early incubation mass were significant in five of seven years. Mass loss during incubation averaged 0.91 ± 0.07 (SE) g/day, was highly variable (CV = 149.5%), and was not influenced by female age (yearling vs. adult) or clutch size. Larger females at the onset of incubation, however, lost more body mass during incubation. We examined individual variation in body mass dynamics with data from 85 adult females with two or more successful first nests in different years. Repeatability of early incubation body mass was high (71.5%) for females, but changes in body mass from early to late incubation varied greatly within females.

Genetics of White-tailed Deer

M. H. Smith and R. K. Chesser

Data collected during fall 1992 included information on the number of deer harvested, demographic structure, and hunter effort expended during the fall hunt. This information was used to calculate pre- and post-hunt population size estimates that were provided to the U.S. Forest Service for planning the 1993 hunts. In addition, these data were added to our data set for the long-term analysis of demographic trends in the SRS deer herd. Tissue samples were collected and during the 1992 hunt were analyzed for genetic variation at electrophoretically determined loci. A subset of these deer representing a range of heterozygosity classes were sent to the laboratory of Dr. Robert J. Baker for analysis of genetic variation in nuclear DNA. The lower jaws were collected from all female deer for analysis of fluctuating asymmetry. Measurements have been completed for these jaws, and analysis of the data will be completed shortly. Measurement of asymmetry of dried eye lenses from previously collected fawns also has been completed. Analysis of this data set will be completed after analysis of the deer jaws. Ovaries were collected from all female white-tailed deer harvested in 1992. Fetal number was obtained by removing the uterus and observing any fetuses. Data were also collected on lactating 1.5 year old females to determine the extent of fawn breeding in the herd. These data sets will be used to evaluate the productivity of female deer on the SRS.

Relationship Between the Liver Fluke, *Fascioloides magna*, and White-tailed Deer on the Savannah River Site

M. Mulvey

Liver flukes are common parasites in the deer of the Savannah River Site. We have developed this host-parasite relationship as a model of macroparasite dynamics. The potential impact of the parasite on SRS deer was examined. Deer are a major component of the ecological community on the SRS and, through public deer hunts, are important to the public perception of the site. Understanding factors, including parasites, that influence deer health and condition are essential to their management.

Flukes and deer tissues were collected from deer harvested during public hunts. Flukes were counted, and fluke and deer tissues were collected for protein electrophoresis. This year we also collected deer abomasum and lungs to determine other parasite prevalence. These will be compared to the fluke data. Data analysis for the 1992 hunt is ongoing. One manuscript has been published, and two additional manuscripts have been prepared for submission.

Population Ecology of Turtles at Ellenton Bay

J. W. Gibbons

Numerous instances can be given where natural habitats have been destroyed as a consequence of human activities, such as coastal development and destruction of freshwater wetlands. As a result, entire populations have been eliminated or significantly reduced in size. Establishing population trends of species in habitats on which the level of human impact is equivocal is more difficult. Long-term studies in protected research sites on the Savannah River

Site (SRS) in South Carolina have permitted us to assess annual population levels of several species of turtles. The results permit a view of natural population fluctuations that can occur in response to presumed normal extremes of environmental variation. Scientific progress in understanding the evolution of life history characters in reptiles is accelerated when the full range of life history phenomena can be studied. Yet, because of temporal funding constraints operative on most researchers nationwide, only short-term studies on short-lived species typically are feasible. However, at SREL, the commitment by DOE to long-term funding has made possible several decades of long-term study on long-lived turtles, many of which do not breed until after 5-12 years of life and continue to breed above age 30. The Savannah River Ecology Laboratory research on SRS turtles has had major impacts on our understanding of environmental sources of selection on reptile life history ecology.

During the past year, our major emphasis has been on the restart of turtle population ecology studies at Ellenton Bay, which were initiated in the Fourmile Branch and intermittently continued through the 1970s and 1980s. This year, because of extensive flooding and a rise in the water level of Ellenton Bay, an additional enclosure fence was installed outside the original 1.2 km fence.

The abundant turtle species (*Trachemys scripta* and *Kinosternum subrubrum*) have been the principal focus, although all turtles encountered at the fences or in one of the pitfall traps are brought back to the lab for individual identification and, if necessary, individual marking. From October 1992 to June 1993, we recorded original captures of 307 turtles distributed among nine species, in addition to 347 recaptures of previously marked turtles. Many of the recaptured turtles were captured previously during a 20-year period from Ellenton Bay and nearby wetlands. One conclusion we may draw from the present data set is that turtle population sizes at Ellenton Bay are in a period of dramatic increase following the drought-induced population crashes we observed during the past decade.

As part of the turtle studies at Ellenton Bay, we radio-tracked more than 140 mud turtles to determine the extent of terrestrial travel and nesting behavior. More than 50 nests have been located for these species for which virtually no previous nesting information was known. One aspect of the research is relevant to reaching an environmentally rational definition of wetlands that includes the surrounding terrestrial habitats.

Recent Publications: Wildlife Studies

Aho, J. M., M. Mulvey, K. Jacobson, and G. W. Esch. 1992. Genetic variability and differentiation among congeneric acanthocephalans. *J. Parasitol.* 78:974-981.

Mulvey, M. and J. M. Aho. 1993. Parasitism and mate competition: Liver flukes in white-tailed deer. *Oikos* 66:187-192.

Rhodes, O. E., Jr. R. K. Chesser, and M. H. Smith. 1992. Assessment of reproductive losses in white-tailed deer. Pages 390-397, in: *The Biology of Deer*, R.D. Brown (ed.). Springer-Verlag, New York.

Rhodes, O. E., Jr., and R. K. Chesser. Genetic concepts for habitat conservation: The transfer and maintenance of genetic variation. *Landsc. Urb. Plan.* (In Press).

A.7. ZOOPLANKTON

Zooplankton in Carolina Bays and Other Temporary Ponds

B. E. Taylor, D. L. Leeper, and A. E. DeBiase

One of the questions that repeatedly arises in our analyses of taxonomic and genetic composition of zooplankton in Carolina bays on the Savannah River Site (SRS) concerns the effect of historic era alteration and longer-term change on the ponds. With M. J. Brooks (Savannah River Archaeological Research Project) and E. Gaiser (doctoral student, University of Georgia), we have begun studies to reconstruct environmental histories of several Carolina bays. One objective is to characterize aspects of change in the landscape, including size, hydroperiod, and connectivity of ponds, which could affect the aquatic communities. The absence of peat and scarcity of other organic materials in sediments of Carolina bays on the SRS led us to explore the analytic possibilities of other materials, including charcoal fragments, siliceous microfossils, and archaeological artifacts.

We focussed our initial studies on Flamingo Bay. The land surrounding Flamingo Bay was cleared and cultivated during the historic era, but its hydrology was not altered by ditches. We obtained radiocarbon dates on charcoal from three strata in the upper half of a one-m core from the deepest part of the basin. These data indicate very low sedimentation rates ($\sim 0.1 \text{ mm}\cdot\text{yr}^{-1}$). Evidently, pre-SRS agricultural activities did not cause substantial infilling of the basin. The southeastern sand rim of the bay contains an archaeological site 200 m long by 70-80 m wide. Using archaeological dates for strata on the southeastern sand rim and the radiocarbon dates for strata in the basin, we estimate that the Flamingo Bay of 10,000 years BP was about one m deeper (2.6 m maximum depth) and nearly twice as large (10-12 ha). We speculate that Flamingo Bay and many other bays may have functioned as shallow permanent lakes rather than as temporary or semipermanent ponds.

Diatom frustules, phytoliths (siliceous material from epidermal cells of grasses and other higher plants), and spicules from freshwater sponges are present in the sediments of Carolina bays, and Evelyn Gaiser is planning detailed analyses of these microfossils for her dissertation. These results, along with additional radiocarbon analyses, will enable us to develop and refine our reconstructions of Carolina bay histories.

We continued regular field sampling at two temporary ponds for our long-term studies on zooplankton dynamics. We now have data for nine years from Rainbow Bay and for five years from Flamingo Bay. At Rainbow Bay, we are completing a two-year study of benthic macro- and microinvertebrates to assess their contribution to the energetic economy of the pond.

Recent Publication: Zooplankton

DeBiase, A. E. and B. E. Taylor. New occurrences of *Eurytemora affinis* and *Epischura fluviatilis*, freshwater calanoid copepods of the family Temoridae, in South Carolina. Am. Mid. Nat. (In Press).

Floyd, M. A. The biology and distribution of oecetis larvae in North America, *Trichoptera: Leptoceridae*. Universal Book Services.

Richardson, W. B. 1992. Microcrustacea in flowing water: Experimental analysis of washout times and a field test. Freshwat. Biol. 28:217-230.

Recent publications: Zooplankton (Cont'd)

- Richardson, W. B. and S. T. Threlkeld. 1993. Complex interactions of multiple aquatic consumers: An experimental mesocosm manipulation. *Can. J. Fish. Aquat. Sci.* 50:29-42.
- Taylor, B. E., A. E. DeBiase, and D. L. Mahoney. Development of the zooplankton assemblage in a new cooling reservoir. *Archiv für Hydrobiologie*. (In Press).
- Taylor, B. E. and W. Gabriel. Optimal adult growth of *Daphnia* in a seasonal environment. *Func. Ecol.* (In Press).

B. WOOD STORK FORAGING AND BREEDING ECOLOGY

The Wood Stork Program is a long-term study of a federally endangered bird species that forages in wetland habitats on the SRS. Observations were made to determine breeding success at the stork rookery near Millen, Georgia, in FY92. Feathers and carcasses were salvaged in the colony for future DNA research, and leg bands were attached to hatchling storks to determine their movement patterns. The Kathwood foraging ponds near Jackson, South Carolina, which were initiated in FY86 were monitored throughout the summer to document use of the ponds by wood storks.

SREL WOOD STORK PROGRAM

Wood Stork Foraging and Breeding Ecology

A. L. Bryan, Jr. and I. L. Brisbin, Jr.

Wood storks returned to the Birdsville Colony in large numbers in 1993. Approximately 330 stork nests have been documented in the colony this season, as compared to a previous high count of 270 nests in 1991. Also, a new colony of wood storks was discovered in Chew Mill Pond, a man-made impoundment about three miles southwest of the Birdsville Colony. This research program now is monitoring reproductive success in both colonies. However, a late-winter storm passing through the Birdsville area delayed nest initiation and egg-laying by these birds, so the reproductive information is not available for this report. Water levels in the Birdsville Colony are dropping rapidly, so raccoon predation of nestlings may be a problem for late-nesting storks. About 40 stork feathers have been collected at the colony and archived at SREL for future DNA research.

The Savannah River Swamp System (SRSS) continues to receive sporadic use by wood storks. Storks were observed during four (22%) of 18 aerial surveys of the SRSS from late February through mid-June, with a maximum of 16 storks on May 18. No wood storks have been observed yet on Par Pond during these 1993 aerial surveys. The Kathwood foraging ponds will be lowered for the storks in July.

Recent Publications: SREL Wood Stork Program

- Bryan, A. L., Jr. 1992. The Savannah River Ecology Laboratory Wood Stork Program: 1991 annual report. Unpublished report to DOE.
- Bryan, A. L., Jr. 1992. The Savannah River Ecology Laboratory Wood Stork Program: 1992 annual report. Unpublished report to DOE.
- Coulter, M. C. 1993. Wood Storks of the Birdsville Colony and swamps of the Savannah River Site: General overview of research findings 1983-1990. SREL-42/UC-66e. Savannah River Ecology Laboratory, Aiken, SC. Four Mile Creek pp.
- Coulter, M. C., and A. L. Bryan, Jr. Foraging ecology of Wood Storks (*Mycteria americana*) in east-central Georgia. I. Characteristics of foraging habitat. Colonial Waterbirds. (In Press).
- Depkin, F. C., M. C. Coulter, and A. L. Bryan, Jr. 1992. Food of nestling Wood Storks in east-central Georgia. Colonial Waterbirds 15:219-225.

C. DEFENSE WASTE PROCESSING FACILITY

Ecological studies related to Defense Waste Processing Facility (DWPF) construction continue to support commitments as specified in the Environmental Impact Statement (EIS) and in the DWPF Environmental Monitoring Plan. Following startup of the DWPF, these studies will provide a comparative database for determining environmental quality and impacts from DWPF operation.

ECOLOGICAL STUDIES RELATED TO THE CONSTRUCTION OF THE DEFENSE WASTE PROCESSING FACILITY (DWPF)

DWPF Construction and an Experiment in Mitigation

D. E. Scott, J. H. K. Pechmann, A. C. Chazal, and R. A. Estes

Construction of the Defense Waste Processing Facility (DWPF) began in late 1983. Before construction, the 600-acre site contained a Carolina bay and the headwaters of a stream. SREL has conducted ecological studies to assess the impact of DWPF construction on these wetlands since FY79. In recent years emphasis has been placed on: 1) monitoring the water quality of peripheral streams that were impacted by DWPF construction, and 2) understanding the population dynamics of amphibian species so that human-induced population fluctuations can be separated from naturally occurring fluctuations.

Water quality monitoring was 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. These data were compared to data from previous years. In general, levels of TSS and turbidity continued to decline in FY93 from high levels during the years of DWPF construction. Water quality measurements will continue in FY94.

When DWPF was built, an entire Carolina bay (Sun Bay) was eliminated. Because Carolina bays are important centers for biodiversity, especially of amphibians, SREL's research has focused on the amphibian community at a control site, Rainbow Bay (RB). Breeding populations of amphibians were censused daily at RB in FY93, and were compared to previous years. Numbers of amphibians breeding at RB, and their reproductive success, varies tremendously from year to year. Amphibian population declines have been of great interest in scientific literature recently; 12 years of data for four species from RB were published in the journal *Science* in 1991 as an example of the extreme variability in amphibian breeding population sizes. Experiments were conducted at supplementary sites, in both aquatic and terrestrial habitats, to determine the importance of factors that drive these fluctuations. Factors in the aquatic environment that influence an individual's body size at metamorphosis, such as larval density, have long-lasting effects on adult traits. Studies of terrestrial influences on population dynamics are ongoing.

Studies have shown that an undisturbed terrestrial buffer zone around bay wetlands is important, and that movement of amphibians among adjacent wetlands may promote long-term persistence. Consequently, a 200-meter area around RB, which is connected to smaller buffer zones around two adjacent ponds, Bullfrog Pond and Pickerel Pond was established as a DOE Research Set-Aside area in FY92.

Recent Publications: Ecological Studies Related to the Construction of the Defense Waste Processing Facility (DWPF)

Krenz, J. D. and D. E. Scott. Terrestrial courtship affects mating location in *Ambystoma opacum*. *Herpetologica*. (In Press).

Pechmann, J. H. K. and H. M. Wilbur. Putting declining amphibian populations in perspective: Natural fluctuations and human impact. *Herpetologica*. (In Press).

Scott, D. E. 1993. Timing at reproduction of pedomorphic and metamorphic *Ambystoma talpoideum*. *Am. Mid. Nat.* 129:397-402.

Recent Publications: Ecological Studies Related to the Construction of the Defense Waste Processing Facility (DWPF) (Cont'd)

Semlitsch, R. D., D. E. Scott, J. H. K. Pechmann, and J. W. Gibbons. 1993. Phenotypic variation in the arrival time of breeding salamanders: Individual repeatability and environmental influences. *J. Anim. Ecol.* 62:334-340.

D. ENVIRONMENTAL STRESSES FROM OPERATIONS

This program is designed to determine the response of aquatic and terrestrial ecosystems to environmental perturbations caused by SRS operations. The following programs currently address specific stresses of concern on the SRS: (1) studies on fish use of natural and impacted aquatic habitats on the SRS including Upper Three Runs Creek and Fourmile Branch, and (2) investigations into the status (either endangered or threatened) of a mussel on the SRS. Technical information necessary for making environmental protection and natural resource management decisions pertinent to maintaining continued compliance with federal and state regulations is provided by these programs.

D.1. ENDANGERED SPECIES

Status of *Elliptio* Mussels on the Savannah River Site

M. E. Mulvey

A report summarizing an initial survey of the SRS for *Elliptio* species has been completed and is in its final revision. Morphological and electrophoretic analyses of *Elliptio* taken from the SRS have identified seven species: *E. icterina*, *E. ravaneli*, *E. complanata*, *E. lugubris*, *E. hepatica*, *E. folliculata* and *E. errans*. A revision of the nomenclature has been completed in collaboration with Dr. George M. Davis, curator of Molluscs, Academy of Natural Sciences of Philadelphia. *Elliptio hepatica*, collected from the Upper Three Runs drainage (Mill and Tinker Creeks), is rare and potentially a species of special concern in South Carolina.

An extensive survey of SRS streams for *Elliptio* has been completed, and morphological and genetic data have been analyzed. Based on this expanded survey, *E. hepatica* remains rare on the SRS. A manuscript describing these results is in preparation. A statewide survey for *Elliptio* has been initiated and will continue to clarify the status of *Elliptio hepatica*.

Red-Cockaded Woodpecker Studies

R. K. Chesser

The habitat of the red-cockaded woodpecker has become highly fragmented throughout its natural range. As a result, birds are concentrated in a mosaic of small populations with little or no migration among the populations. Although this metapopulation structure is relatively common for threatened and endangered species, predictive models for risk assessment, which would facilitate the development of adequate management plans to restore the species, have not been developed. The goal of this program is to develop sound methods for successful reintroduction of the red-cockaded woodpecker on the SRS, for maintaining virile and viable populations for indefinite periods of time, and for conserving genetic variation in the species. Recently published estimates of effective sizes and population viabilities in red-cockaded woodpeckers are incomplete, and the utility of those approaches are of limited value in design of long-term management strategies. Tactics for genetic exchange among groups of remaining woodpecker populations largely have been ignored in the predictive nature of the models. In the past year this program has developed and completed models for: 1) predicting the utility of genetic exchange on maintenance of gene diversity and population viability, 2) methods of determining effective population sizes from empirical genetic analyses, 3) predicting the effects of various rates of habitat fragmentation on the viability of affected populations, 4) determining the effects of overlapping generations in metapopulation structures on the rate of loss of gene diversity and population viability, and 5) documenting the effects of various tactics of genetic exchange (migration), founder representation, and re-introduction programs on the fate of genetic variation. This method also determines optimal methods of exchange for maximum maintenance of gene diversity, predicting the advantages of group interactions in and among social units (as in red-cockaded woodpeckers) and how such units may influence the distributions of gene diversity. Future studies are being directed toward investigating spectra of probability distributions for population viabilities for genetic and demographic characteristics and their joint effects on long-term maintenance of managed populations. The methods developed in this program will serve not only as aids for management of the red-cockaded woodpeckers, but also

for many other species in the future. Field programs investigating the movements and population characteristics of flying squirrels on the SRS also have been initiated over the past year. These studies will provide valuable information regarding potential competition of flying squirrels and woodpeckers for nesting habitat.

Recent Publication: Endangered Species

Chesser, R. K., O. E. Rhodes, Jr., D. W. Sugg, and A. F. Schnabel. Effective sizes in subdivided populations. Genetics. (In Press).

Davis, G. M. and M. Mulvey. Species status of Mill Creek *Elipito*. (for SRS-NERP Report).

Mulvey, M. and S. M. Bandoni. Genetic variation in the M-line stock of *Blomphalaria glabrata* (Mollusca: Pulmonata). J. Helminth. Soc. Wash. (In Press).

D.2. FISH

Ecology of a Representative Species; Population Genetic Structure of Selected Fishes; and Fluctuating Asymmetry Analysis in Selected Fishes

G. K. Meffe

Ecology of a Representative Species

Comparative study of growth and reproduction in the dusky shiner (*Notropis cummingsae*) indicates that populations in Fourmile Branch (recovering from years of thermal discharge) have more rapid growth and greater food resources than control populations in Upper Three Runs Creek. This is most likely because of higher productivity in this system (more sunlight), combined with broader resource availability because of fewer competing species. Reproductive output of these fish in Fourmile Branch also is much higher than that in Upper Three Runs Creek; this is principally because of the larger individual size in Fourmile Branch, but also remains higher when the size difference is factored out. The results of this work are being finalized and readied for publication.

A large fraction of the work with dusky shiners has been devoted to quantification of how storage lipid composition varies among populations, sexes, life stages, and seasons. Lipid levels of dusky shiners in Fourmile Branch tend to be higher than those in fish from Upper Three Runs Creek in both sexes at all life stages. There is a dramatic seasonal cycle of lipid accumulation and depletion associated with reproduction. Female dusky shiners in Fourmile Branch accumulate and store lipids through fall and winter, and lipids then are depleted during the summer spawning season. This pattern contrasts with Upper Three Runs fish, where there is no apparent accumulation of lipids until just before the spawning season, and where lipids are accumulated to a lesser extent than seen in the Fourmile Branch population.

Population Genetic Structure of Selected Fishes

Data are being analyzed on the genetic structure of two species of SRS fishes, the dusky shiner (*Notropis cummingsae*) and the pirate perch (*Aphredoderus sayanus*). The very large data set now has been edited and cleared of errors and is being analyzed by the BIOSYS statistical package. We will determine genetic diversity and compare spatial genetic structures of these species, particularly with respect to possible influences of the effluent treatment facility on Upper Three Runs Creek.

Fluctuating Asymmetry Analyses in Selected Fishes

The same two species of fish from the genetics study are being analyzed for developmental disturbances by measuring deviations from bilateral symmetry (known as fluctuating asymmetry). Collaboration on data analysis is being pursued with Dr. Richard Strauss of Texas Tech University, an expert on morphological analyses.

Responses of Fish in Pond C to Acute and Chronic Thermal Stress

J. D. Congdon and R. U. Fischer

For about 30 years, bluegill have survived severe and unpredictable heating of Pond C by P-reactor. Bluegill escaped lethal temperatures by occupying one of four relatively small distinct refuge areas with cooler water. The refuges are characterized by reduced food availability, virtually no habitat structure, and increased interactions with predators. In response to demands of avoiding predators and foraging in an environment with reduced structure, we designed experiments to determine how the morphology and related performance traits of bluegills have changed in response to both direct and indirect effects of heated effluent.

To answer questions related to changes in morphology and performance traits, we collected approximately 150 bluegill from Pond C (heated site) and Par Pond (normothermic site) during periods of reactor operations and from both sites two years after reactor shut down. In addition, 100 bluegill from Clarks Hill Reservoir were collected to be used in the morphological comparison as a extra control group. Twelve morphological traits (including length, depth and fin shape) were measured for each fish from all samples. Comparisons between sites revealed that overall body length increased and body depth decreased in Pond C bluegill as compared to those from Par Pond and Clarks Hill. In addition, in Pond C fish the depth of both the pectoral and anal fins increased while fin lengths decreased when compared to those from Par Pond and Clark Hill. The morphological changes resulted in a more streamlined and fusiform shaped fish in Pond C.

The morphological changes in Pond C bluegill are associated with greater burst and sustained speed compared to bluegill from Par Pond. The combination of morphological and performance traits make Pond C bluegill more effective at avoiding predators and foraging for prey in structurally reduced habitats.

We also continued to make collections from both sites for determination of life-history differences between Pond C and Par Pond bluegill. The collections and subsequent analyses have shown that Par Pond bluegill mature later and at a larger size as compared to bluegill from Pond C. We plan to continue sampling both sites to determine if a genetic difference exists between Pond C and Par Pond bluegill.

E. ECOSYSTEM ALTERATION BY CHEMICAL POLLUTANTS

These studies in biogeochemical ecology and water quality provide information necessary in making environmental protection and natural resource management decisions based on radioecological and chemical perturbations of various ecosystems. Studies focus on the fate and effect of pollutants that are released from SRS operations where baseline information is not available. Studies of these environmental transport processes should provide predictive capability to the Department of Energy.

E.1. CYCLING OF COAL/FOSSIL FUEL CONTAMINANTS

Contaminants From Coal and Other Fossil Fuels

D. C. Adriano

A major goal of this program has been to investigate the release and biogeochemical cycling of contaminants from coal piles and ash basins, particularly as they relate to potential contamination of soils, surface waters, and ground waters. Data have been generated and analyzed as to the extent of contamination in soil, in ground waters and adjacent vegetated areas. It is now known that runoff effluents from coal piles at the SRS, particularly in the D-Area, could contaminate groundwaters; in addition, the leachate effluents from the ash basin/coal reject landfill also can contaminate the ground water as well as create an environment that is unfavorable for the establishment of native vegetation.

Recently, efforts have focused on evaluating the potential benefits of using fly ash as a composting constituent. This material could be used as a soil amendment on degraded lands, such as borrow pits on the SRS, and in nurseries. Efforts also will be directed toward remediating stressed vegetation areas in D-Area. This may involve manipulation of chemical properties of the soil substrate to be able to sustain plant growth. Five coal-burning power stations on the SRS provide excellent field sites for this research, which currently involves collaborative efforts with the Savannah River Forest Service.

A new field study was initiated in the spring of 1992 to study the feasibility of mixing fly ash with organic matter as a soil amendment; the source of organic matter is chicken manure. The rationale for using the manure was to enhance the fertilization potential of the fly ash because this material is known to be low in major plant nutrients, except potassium. A native shrub, beauty berry (*Callicarpa americana*), was planted. This species also provides a suitable food for wildlife. A study was initiated in July 1992 involving the application of high tonnages of fly ash from the South Carolina Electric Power facility in Beech Island, South Carolina. Approximately 10 cm of coal residue will be placed on the surface in test trials. The focus is on the effect of this material on soil-plant-water relations and groundwater quality.

Environmental Chemistry of Fossil-Fuel Derived Organic Contaminants

G. L. Mills

Numerous studies have examined the behavior of organic solutes in relatively simple solution-solid phase mixtures. Many of these studies have been limited to a single solute. However, petroleum distillates such as kerosene, diesel oil, and gasoline, are a complex mixture of hydrocarbon molecules including normal, branched, and cyclic aliphatic compounds, as well as mono- and polycyclic aromatic hydrocarbons (PAH). The sorptive behavior and consequent mobility of these hydrocarbon components will be influenced profoundly by changes in both the solution and solid phase in petroleum contaminated systems. Higher molecular weight aliphatic components will sorb preferentially to the solid phase, thus increasing the hydrophobicity of the surface. This may be particularly important in subsoils or aquifer sediments where the natural organic matter content is low. In addition, in low carbon environments, specific adsorption rather than partitioning to natural organic matter, may be the predominant sorption mechanism. Under these conditions, competition among the mixture of solutes for sorption sites needs to be considered explicitly. In the source region of the

contaminated site, often referred to as the near-field, both the solution and solid phase are saturated with hydrocarbons. Consequently, the near-field region generally contains a separate phase of petroleum hydrocarbons, termed "free product." As the petroleum water mixture migrates away from the source region, the distinct petroleum phase forms dispersed micelles in the aqueous phase. These hydrocarbon micelles provide a partitioning environment for aqueous solutes. The equilibrium parameters and rates of solute transfer between these phases is poorly understood but necessary for prediction of the mobility of hydrocarbon contaminants.

We have initiated laboratory column studies to evaluate the sorptive behavior of selected PAH in SRS aquifer sediments contaminated with weathered diesel oil. Unconsolidated sediments were collected from the Tobacco Road Formation on the SRS and characterized using a variety of physical and chemical techniques. Weathered diesel oil as free product was collected from a contaminated site in Lexington County, South Carolina, with the assistance of the South Carolina Department of Health and Environmental Control (SCDHEC). The oil was characterized using gas chromatography and gas chromatography-mass spectrometry (GC-MS) to determine the aliphatic and aromatic components and to ascertain the degree to which the oil had been weathered. The oil will be sorbed onto the aquifer material at varying percent surface coverage to simulate a progression from the near-field to the far-field in a contaminated system. Selected PAH labelled with deuterium have been synthesized, which will allow multi-solute mixtures to be used in our column studies. The deuterium labelled compound will allow us to distinguish experimental solutes from the indigenous PAH in the diesel oil using GC-MS in the selected ion monitoring mode.

This is a novel approach for studying multicomponent solute mixtures and may provide significant advancement in our understanding of sorption in complex mixtures. The PAH selected in our study encompass a range of solute polarity and include both nitrogen and sulfur heterocyclic compounds. We have recently completed Br⁻ ion tracer studies to determine the hydrodynamic properties of the column system. Preliminary studies using a single solute PAH (anthracene) mobile phase in uncontaminated aquifer material also have been completed.

Recent Publication: Cycling of Coal/Fossil Fuel Contaminants

- Anderson, M. A., P. M. Bertach and L. W. Zelazny. 1993. Multicomponent transport of metals through soil subjected to coal pile runoff under steady saturated flow. Pages 137-164 in: R. F. Keefer K. S. Sajwan (eds.). *Trace Elements in Coal and Coal Combustion Residues*. Lewis Publishers, Chelsea, MI.
- Carlson, C. L. and D. C. Adriano. 1993. Environmental impacts of coal combustion residues: A review. *J. Environ. Qual.* 22:227-247.
- Keefer, R. F. and K. S. Sajwan (eds.). 1993. *Trace Elements in Coal and Coal Combustion Residues*. Lewis Publishers, Chelsea, MI. pp. 308.
- Klubek, B., C. Carlson, J. Oliver, and D. C. Adriano. 1992. Characterization of microbial abundance and activity from three abandoned coal ash basins. *Soil Biol. Biochem.* 24:1119-1125.
- Sandhu, S. S., O. L. Mills, and K. S. Sajwan. 1993. Leachability of Ni, Cd, Cr, and As from coal impoundments of different ages on the Savannah River Site. Pages 165-182 in: R. F. Keefer and K. S. Sajwan (eds.). *Trace Elements in Coal and Coal Combustion Residues*. Lewis Publishers, Chelsea, MI.

E.2. RADIONUCLIDE CYCLING IN POND B

Functional Processes in Vertebrates

I. L. Brisbin, Jr.

During the past year, a thesis research program was completed, allowing an evaluation of the levels of radiocesium contamination transferred by nesting female wood ducks to their eggs in nest boxes established in the Pond B reservoir. Radiocesium levels in egg albumin were higher than in egg yolk, and they also were more variable. Whole egg radiocesium levels were related to the degree to which the hen foraged on the Pond B reservoir vs. nearby uncontaminated wetlands during the preceding day, the time when egg components were being formed in the hen's body. Plans to release a tamed flock of mallard ducks on Pond B to document radiocesium uptake patterns have been further delayed because excessive predation on the captive breeding flock, and problems in obtaining replacements for whole-body gamma counting equipment.

Annual night alligator spotlight census cruises and slider turtle trapping/marketing programs are scheduled for completion in the summer of 1993. Despite increased trapping efforts, only a few turtles were captured in the reservoir during the past year. A draft manuscript has been completed as part of a doctoral thesis aimed at using data from five years of turtle trapping in Pond B. These data were used to derive and test a model designed to predict the pattern and rate of radiocesium uptake and concentration by these animals from what is known about their food habits and feeding rates under free-ranging conditions.

Laboratory studies continued on the growth and development of American alligators maintained on a dry formulated ration and/or provided with radiocesium-contaminated bass from the Pond B reservoir as a sole source of food. Semi-annual weights and measurements of these animals indicate continuing, but declining growth of the animals maintained on the formulated ration. The alligators receiving contaminated Pond B bass as food continue to increase their radiocesium body burdens but at a diminishing rate which, in the case of one individual, seems to be approaching an asymptote.

A master's thesis was completed describing the spatial and temporal variation in mosquitofish in Pond B. Data from fish collected in 1991 revealed important differences in radiocesium distribution patterns from those of fish sampled from the same locations in 1987.

Recent Publications: Radionuclide Cycling in Pond B

Brisbin, I. L., Jr. Birds as monitors of radionuclide contamination. *in*: R. W. Furness (ed.), *Birds as Monitors of Environmental Change*. Chapman and Hall, London. (In Press).

Colwell, S. V. 1993. Radiocesium patterns in wood duck eggs and nesting females on a contaminated reservoir. Master's Thesis, The University of Georgia, Athens, GA.

Kennamer, R. A., C. D. McCreedy, and I. L. Brisbin, Jr. Patterns of radiocesium contamination in eggs of free-ranging wood ducks. *J. Wildl. Manage.* (In Press).

Pinder, J. E., III, J. J. Alberts, J. W. Bowling, D. M. Nelson, and K. A. Oriandini. 1992. The annual cycle of plutonium in the water of a warm, monomictic reservoir. *J. Environ. Radioact.* 17:59-81.

E.3. SOIL/SEDIMENT REMEDIATION

Soil/Sediment Remediation at Par Pond

D. C. Adriano

This is a new program created by redirecting funds from the old Biobarrier Program. A field plot study was initiated in the fall of 1992 near the SREL boat dock at Par Pond. The exposed lakebed sediment was prepared to simulate garden plots. This study was precipitated by previous dose assessments by Dr. F. W. Whicker indicating that ingestion of food products raised in this area by a hypothetical lake basin inhabitant would represent the greatest exposure risk. Hence, this study is primarily an evaluation of various remedial options to enhance the quality of the food chain. Various remedial measures that already have been tested widely, as well as potentially innovative ones, are being evaluated. The efficacy of the various techniques are to be measured using crop indicators. For the fall of 1992 collards and cabbages were grown and measured for ^{137}Cs activity. Other radionuclides also will be evaluated, such as ^{90}Sr , and transuranic elements. In addition to radionuclides, mercury also will be evaluated, because this metal is found in the lakebed sediments. The projected schedule for this project is to conduct the experiments for at least two years, or as long as the lake is not refilled.

Recent Publication:

Adriano, D. C., J. Albright, F. W. Whicker, and I. K. Iskandar. Remediation of metal and radionuclide-contaminated soil. Special volume from the Second International Conference on the Biogeochemistry of Trace Elements: Remediation of Metal Contaminated Soils. Applied Science Publishers, London. (In Press).

E.4. ENVIRONMENTAL GEOCHEMISTRY AND TOXICOLOGY OF URANIUM

Environmental Geochemistry of Uranium

P. M. Bertsch

The Lost Lake, Tim's Branch (TB), and Steeds Pond regions of the Upper Three Runs Creek watershed have received considerable amounts of U, Ni, Al, Cr, and Cu from the M-Area fabrication facilities. These contaminants are largely immobilized in the surrounding soils and stream sediments. There is concern as to the potential impact of these metals on aquatic biota within the Tim's Branch system and the potential for transport of these metals to Upper Three Runs Creek (UTRC), which empties into the Savannah River. This research program was initiated with the objectives of examining the distribution, fate, and mobilization potential of U and other introduced metals within and from contaminated sediments, and to examine population level responses of selected aquatic biota to U in the Tim's Branch-Steeds Pond regions of the Upper Three Runs Creek watershed.

Research is being conducted at the National Synchrotron Light Source located at Brookhaven National Lab (Brookhaven, NY) to determine Fe, Mn, U, Cu, Cr, and Ni concentrations and associations, and U binding environments in size-fractionated stream sediments and in suspended colloids from the water column of Tim's Branch and surrounding groundwater. The data on elemental associations are being compared, where possible, to those derived from indirect chemical sequential extraction techniques. Specific information on the chemical speciation of contaminant metals in soils is a prerequisite for the development of adequate models for predicting their mobility and fate in the environment and for the development of cost effective, yet environmentally sound remediation strategies. The utilization of synchrotron based X-ray absorption spectroscopy (XAS), coupled with microanalytical capabilities, has provided direct information on the chemical speciation of U in micro-regions of contaminated soils and sediments sampled at two former Department of Energy uranium materials processing facilities. Using X-ray absorption near edge structure (XANES), the predominant oxidation state of U in 50 to 300 μm regions of the contaminated sediments and other qualitative information concerning U bonding environments were inferred.

In most of the regions examined, U was present as the hexavalent species; however, localized regions of exclusively tetravalent U were discernible in soils from one of the sites, based both on the energy of the central edge position and on the absence of diagnostic features in the high energy regime of the central absorption feature in the XANES spectra that are characteristic of the uranyl U(VI) species. Complete X-ray fluorescence spectra collected at these same regions demonstrated the predominant co-association of one form of the hexavalent U species with Fe and Mn, suggesting a surface association with oxyhydroxide phases within the soil. A second hexavalent U population and all of the observed tetravalent U species were present in regions depleted of elements normally associated with soils and sediments and were relatively enriched in Cu and/or Ni, suggesting the existence of discrete U containing phases. This report represents the first application of synchrotron-based XAS utilizing microanalytical techniques to the study of metal speciation in soils and sediments, and demonstrates the potential utility of this method for such applications.

Intensive field sampling studies initiated this past winter have focused on the transport and chemical speciation of U in the Tim's Branch system during episodic events. Samples have been collected around the hydrography for three storms and the data is being analyzed.

Toxicology of Uranium

M.C. Newman

Enhanced tolerance to uranium in the Steeds Pond population of mosquitofish was assessed by comparing times-to-death (TTD) of fish bred from the Steeds Pond population to those of fish from Risher Pond. Failure time analysis indicated significantly higher tolerance in the Steeds Pond-derived population. A genetic survey of Tims Branch and the main stream of Upper Three Runs Creek also indicated an abrupt shift in allele frequencies in Tims Branch. Whether this shift is a consequence of any toxic effect of associated metals or a natural genetic bottleneck remains uncertain. The manuscript describing these findings will be submitted for publication this fall.

Sediment preference studies were completed for two benthic species, the asiatic clam (*Corbicula fluminea*) and a snail (*Campeloma decisum*). Negative (clean sediment) and positive (D-area, fly ash contaminated sediment) controls were paired alternately against Steeds Pond sediments. *Corbicula* avoided sediment from the ash basin, but not Steeds Pond. No significant avoidance of contaminated sediments was noted for *Campeloma*. Consequently, *Corbicula* but not *Campeloma* was selected for further study. *Corbicula* spatial distribution and movement were examined, and no statistically significant effect of sediment type on spatial patterning of clams was detected. The results are being incorporated into a simulation model to predict the effect of patch size on the likelihood of an individual *Corbicula* escaping a patch of contaminated sediment.

Preliminary studies of the use of a bacterial bioluminescence assay (Microtox[®]) for toxicity of sediments and water of Tims Branch have been initiated. Linkage of metal coordination chemistry to bioavailability also is being explored as a quantitative means of assessing metal synergisms. Water and sediment from a transect in Tims Branch will be collected and Effective Concentrations determined during the winter of 1993.

Recent Publications: Environmental Geochemistry and Toxicology of Uranium

Bertsch, P. M., D. B. Hunter, S. R. Sutton, S. Bajt, and M. L. Rivers. *In situ* chemical speciation of uranium in soils and sediments by micro x-ray absorption spectroscopy. Environ. Sci. Tech. (In Press)

F. WETLAND SYSTEMS

This research documents the early recovery of wetland floodplain ecosystems from the effects of thermal and other discharges from SRS operations. Emphasis is on vegetation establishment physiological tolerances, and natural development of plant communities, on experimental approaches to enhance the rate of succession in highly disturbed floodplain forests, and on environmental transport of contaminants. In addition, recovery of the lower food chain in altered stream systems is being documented and compared with in-stream and floodplain communities in Upper Three Runs Creek. Research is directed toward recovery of both ecosystem structure and processes. This information will allow prediction of stream recovery rates and will also serve as a baseline for prediction of contaminant movement in SRS streams.

F.1. WETLANDS

Inundation and Salinity Stress on Wetland Woody Species

K. W. McLeod, J. K. McCarron, and W. H. Conner

Coastal forests have been exposed to a continuing array of environmental stresses, due to sandy substrates and proximity to the ocean. In the past, the environment changed slowly and species had sufficient time to adapt. With the anticipated global climate change, coastal areas are predicted to be increasingly inundated, because of sea level rise and land subsidence. It is expected that these changes will occur much more rapidly than in the past. Thus, species may not have sufficient time to adapt to the sea level rise and the stresses of increasing inundation and salinity.

A study was initiated to determine the relative tolerances of woody species to inundation and salinity from chronic exposures, which might occur with sea level rise. This report focuses on the physiological responses to the treatments and potential acclimation ability of several tree species.

Seedlings of green ash (*Fraxinus pennsylvanica*), water tupelo (*Nyssa aquatica*), tallow tree (*Sapium sebiferum*), and bald cypress (*Taxodium distichum*) were used in a 2 X 3 complete factorial experiment, with varying soil moisture conditions (watered or loaded by 10 cm of water) and salinity (0, 2 or 10 ppt). At various intervals over the growing season, rates of photosynthesis, conductance, and transpiration were determined diurnally with a LICOR 6200 Portable Photosynthesis System. Xylem pressure potential (XPP) was also measured diurnally with a PMS pressure chamber.

Sea level rise, which would chronically inundate coastal forests with 10 ppt, would kill seedlings of all four species. Tallow tree seedlings survived the longest, but on the first sampling date exhibited signs of salinity stress. All other species exhibited intolerance to inundations with 10 ppt.

Of the other five treatments, photosynthesis of all four species in late September was most affected by the 2 ppt salinity inundation. This response was the result of chronic exposure. The greatest initial reduction in photosynthesis for three of the four species was observed in the 10 ppt salinity. Green ash seedlings watered with 10 ppt exhibited an ability to acclimate to these salinity levels. The photosynthetic response was even more remarkable considering that the 10 ppt watering treatment was consistently more water stressed at dawn for all species except tallow tree. Thus, watering with 10 ppt salinity definitely increases the potential stress on seedlings of these species, but because the seedlings were well watered, the full effect of the 10 ppt salinity was not expressed.

Regardless of salinity, photosynthesis of tallow tree and green ash were more sensitive to inundation. Thus, any environmental change that would increase flooding would harm these species more than bald cypress and water tupelo. Only when inundation is coupled with a salinity increase was photosynthesis of water tupelo or bald cypress affected.

From this data several potential scenarios of the impact of sea level rise can be estimated. If sea level rise leads to the increased ponding of water but not salinity in the coastal forests, then tallow tree and green ash would be more detrimentally affected than bald cypress and water tupelo. But, if sea level rise leads to a slight increase in salinity (<2 ppt) of the ponded water, then all four species would be impacted, with less reduction in photosynthesis for bald cypress

and water tupelo. If sea level rise causes inundation of up to 10 ppt salinity for a month or more, seedlings of none of these species will persist.

The final scenario would involve the impact of sea level rise in contributing to the occasional watering of the coastal forest with saline water through high tides, small storm surges, tidal flushing of low lying areas, etc. The impact of this type of event would be minimal for these four species, except in the rare instance where drought followed with soil salinization. Seedlings of all species would be less drought tolerant, with bald cypress and water tupelo more sensitive to drought effects than green ash or tallow tree.

Dynamics of Woody Plant Regeneration in Floodplain Forests

R. R. Sharitz, R. H. Jones, and P. M. Dixon

Studies of the dynamics of wetland forest species and the effects of the hydrologic regime on the recruitment and growth of woody species are continuing. Four sites were chosen to include frequently and infrequently flooded areas within the floodplains of a small river (Upper Three Runs Creek) and a large river (Savannah River). Several demographic processes were consistent for all four forests, as well as for floodplain forests described in other published studies. Smaller-seeded species had larger numbers of seeds dispersed, more germinants and more established seedlings than larger seeded species. Seed size, however, was not clearly related to seedling survival. Published rankings of shade and flood tolerance also were unrelated to survival, at least during the first growing season after germination. Seedling survival rates were lowest during the first growing season and higher in subsequent years. Within a growing season, early germinants had greater survival than later germinants. For some species, survival was related negatively to basal area of conspecific adult trees.

Some aspects of the regeneration process were more site-specific. Within species, seed fall densities relative to adult tree abundance differed across forests by an order of magnitude. First-year seedling mortality rates were affected significantly by site and site X species interactions. Mortality in subsequent years also was significantly affected by site. Although the role of flooding in site-specific mortality was not clear, small changes in elevation within flooded sites were correlated with changes in germination and survival for some species.

In each of the forests, seedling composition also differed from the overstory composition. For example, sweetgum was abundant in the overstory of all four forests but was far more prevalent in the seedling layer of the flooded than unflooded forests. Oaks also occurred in the overstory of all sites but were rare as seedlings in the large river sites. These findings suggest that species composition of the overstory will likely change over time as canopy trees die and are replaced by seedlings and saplings of different species.

Monitoring Rare Plants and Modelling Historical Carolina Bay Hydrology

P. M. Dixon

Populations of two rare plant species, *Echinacea laevigata* and *Croton elliotii*, have been monitored on the SRS. *Echinacea laevigata* was listed as a federally endangered plant in December 1992. Since 1989, the one *Echinacea* population on the SRS has been declining

slowly, with few plants flowering each year. This population is biologically unusual in being one of two Coastal Plain populations. Most of the known *Echinacea* populations are found on geologically altered rocks in the Piedmont. When the species was placed on the Federal Endangered Species List, the Coastal Plain populations were considered separately from the remaining populations because they were considered to have been introduced.

In August 1992, we conducted a range-wide survey of the population genetics of *Echinacea laevigata* to determine if the Coastal Plain populations were genetically different from inland populations. There were no detectable allozyme variations among individuals and among populations. Preliminary analysis of the data suggests that the SRS population is not unusual, and that the SRS population should not be considered separately from the remaining populations.

No *Croton elliotii* were found in the October 1992 survey because the water levels in its habitat, the Carolina bays, were extremely high. The 10m X 10m permanent plots used to census *Croton* were established during the 1989-1990 drought. All permanent plots were under water from 1992 through the summer of 1993. Water levels have dropped during June and July 1993. Because *Croton* seedlings germinate in July and August, populations may re-establish if the water levels remain down.

Vegetation Disturbance and Maintenance of Species Diversity in Intermittently-Flooded Carolina Bays

L. K. Kirkman and R. R. Sharitz

Cyclical changes of the vegetation in four grass-dominated Carolina bay wetlands on the SRS were examined during a ten-year cycle of drought and re-flooding. During dry periods, fire and soil disturbance (from tillage for agricultural purposes or rooting by pigs) are common in Carolina bays of the region. The effects of these drought-related disturbances were examined through field experiments that manipulated fire regime and soil disturbance (tillage). Vegetation composition and cover within dominant vegetation types before and after treatments were examined, and the seed bank was quantified.

Burning did not affect species richness, evenness or diversity, but soil tillage increased diversity, including both evenness and richness. Percent similarity of the vegetation before and after disturbance was greater in the burning treatment than in the soil tillage treatment, probably because of greater disruption of perennial vegetation rhizomes by tillage. Several native fugitive species increased following disturbance, indicating that species coexistence in the Carolina bay wetlands depends on the life history characteristics of residual vegetation, as well as that of seed bank species.

The seed bank was larger (72,600 seeds per square meter) and species richness was greater (108 species) than reported for most other freshwater wetlands. The floristic composition of the seed bank did not resemble the standing vegetation in patches dominated by the large perennial grasses (*Panicum hemitomon*, *Leersia hexandra*, and *Andropogon virginicus*). In contrast, seed bank samples associated with vegetation dominated by an annual forb (*Iva microcephala*) or the small perennial grasses (*Panicum wrightianum* or *P. acuminatum* var. *unciphyllum*) more closely reflected the standing vegetation.

Species appear to persist with recurring and multiple disturbances because of seed banks, rhizomes, morphological plasticity during inundation, sexual reproduction following inundation, and perennial growth forms. Conservation management of intermittently-inundated wetlands should incorporate techniques to foster maintenance of endemic species richness and the

recruitment of rare species. Episodic disturbance regimes during periods of drought may be desirable to partially remove aggressive perennial vegetation for the recruitment of less common species.

Recent Publications: Wetlands

Jones, R. H., R. R. Sharitz, P. M. Dixon, D. S. Segal, and R. L. Schneider. 1993. Woody plant regeneration in four floodplain forests. *Ecol. Monog.* (In Press).

Kirkman, L. K. and R. R. Sharitz. 1993. Growth in controlled water regimes of three grasses common in freshwater wetlands of the Southeastern USA. *Aquat. Bot.* 44:345-359.

Kirkman, L. K. and R. R. Sharitz. 1993. Vegetation disturbance and maintenance of species diversity in intermittently-flooded Carolina bays of South Carolina. *Ecol. Appl.*

Sharitz, R. R. and W. J. Mitsch. 1993. Southern floodplain forests. Pages 311-372 in *Biodiversity of the Southeastern United States/Lowland Terrestrial Communities*. W. H. Martin, S. O. Boyce, and A. C. Echternacht (eds.). J. Wiley Pub.

F.2. LOWER FOOD CHAIN

Invertebrates, Microbes and Organic Matter in Aquatic Systems J V. McArthur

We have completed the installation of sampling tubes in both Meyers Branch and Tinker Creek watersheds that allow us to sample hyporheic organisms. We have collected several taxa that are new records for South Carolina and have increased our understanding of the dimensions and composition of the subsurface aquatic habitat. In addition we have begun studies designed to compare and contrast various sampling techniques. A new graduate student will evaluate these sampling methods in both disturbed/recovering systems (Fourmile Branch) and undisturbed streams (Meyers Branch and Upper Three Runs Creek).

We have completed a survey of Meyers Branch to document the movement of the asiatic clam, *Corbicula fluminea*. Several years ago we found that this clam had moved from Steel Creek into Meyers Branch. At that time its distribution was limited, but today this clam can be found almost the full length of Meyers Branch. This rapid movement is important, and any potential negative impacts need to be considered with respect to the native bivalve fauna in other streams on the site.

After considering the uniqueness of Upper Three Runs Creek in the context of species richness/diversity/endemism, we have begun an analytical/theoretical paper to consider various reasons for these observations. This work is primarily literature-based but has shown that Upper Three Runs is among the most unique streams in the world. This work will be of great value in determining the best management strategy for this resource.

Recent Publications: Lower Food Chain

Floyd, M. A., J. C. Morse, and J V. McArthur. 1993. Aquatic insects of Upper Three Runs Creek, Savannah River Site, South Carolina. Part IV: Caddisflies (Trichoptera) of the lower reaches. *J. Entomol. Sci.* 28:85-95.

Floyd, M. A. The biology and distribution of oecetis larvae in North America, *Trichoptera: Leptoceridae*. Universal Book Services.

F.3. ENVIRONMENTAL TRANSPORT PROCESSES

Physicochemical Factors Regulating Facilitated Contaminant Transport

P. M. Bertach

The chemical speciation and solid phase partitioning of metals and contaminant organics control their mobility in the environment and their bioavailability and toxicity. Our research over the past year has continued to examine both fundamental and more applied aspects of chemical speciation and the associated implications for contaminant mobility and toxicity, with special emphasis on physicochemical factors involved in facilitated transport of contaminants.

Characterizing mobile colloids in the subsurface environment has become increasingly important in light of the growing number of reports of colloid-facilitated transport of contaminants. Mobile colloids were collected from 13 lysimeters containing reconstructed profiles of two Ultisols. In both soil types, the highly charged mobile colloids were enriched with kaolinite, Fe-oxides, and gibbsite and were more dilute in quartz and hydroxy-interlayered vermiculite (HIV) than the soil total-clay fraction. Their diameters were less than 1000 nm and had bimodal size distribution: the larger colloids consisted primarily of quartz, kaolinite, and HIV, whereas the smaller ones consisted primarily of Fe-oxides and gibbsite. The water-dispersible clay ($< 2 \mu\text{m}$ fraction in suspension after 16 h of shaking in water) provided a better approximation of the size and mineralogy of the colloids than did the total-clay fraction. This was attributed to the dispersive properties of water being more like those of the soil pore water than the dilute (NaPO_3), NaOH solution used to disperse the total-clay fraction. Dispersibility measurements and the presence of organic coatings on the colloids indicated that the colloids originated largely from the Ap horizon. The critical flocculation concentration (CFC) of the water-dispersible clays in the Ap horizon predicted the soil Ph and solution ionic strength conditions necessary for mobile colloid release from the 13 lysimeters. The general success of the predictive capabilities of the CFC test was attributed to identifying the correct soil horizon and fraction and using sandy texture soil profiles with rather limited potential of particle straining. Sodium Adsorption Ratio, even at levels less than two (mol m^{-3})^{0.5} in the Ap horizon, was correlated to mobile colloid concentrations. The presence of highly charged clays in a size range easily transported through the subsurface may make such weathered systems especially conducive to colloid-facilitated transport of contaminants.

Quantitative information regarding landscape sources and pathways of organic matter transport to forest streams is important for assessing the impact of terrestrial processes on aquatic ecosystems and for evaluating the potential risk of facilitated transport of contaminants by natural organic constituents. We quantified organic carbon flowing from Fourmile Branch, a blackwater stream draining a 12.6 km² watershed on the upper Atlantic Coastal Plain in South Carolina, and used a hydrologic approach to partitioning this outflow between its various pathways from upland and wetland forest sources. Results of this study indicate that 28.9 tonnes C yr⁻¹ were exported by stream flow, which was estimated to be 0.5% of the annual C input from forest detritus to the watershed. Upland forest, which covers 94.4% of the watershed, contributed 2.0 tonnes C yr⁻¹ to stream flow, which amounted to only 0.4% of detritus annually produced by the upland forest. Organic matter was transported from uplands to the stream almost entirely through groundwater. Upland topography in this watershed is apparently too small for interflow and soils too porous for overland flow to occur in significant quantity. Riparian wetland forest, which covers 5.6% of the watershed, contributed the remaining 26.9 tonnes C yr⁻¹ to stream flow, which amounts to about 10.2% of the detritus annually produced

by the wetland forest. Dissolved organic carbon leached from wetland soil during baseflow periods contributed half of all organic carbon entering Fourmile Branch. Wetlands also contributed organic carbon to baseflow by channel debris, and to runoff from rainfall by further leaching and mobilization from wetland soil by overland flow. These results suggest that upland soils in this region are very efficient at removing organic matter from percolating soil water and quantitatively confirm the dominant role that riparian wetland soils play in contributing organic matter to coastal plain streams.

Recent Publications: Environmental Transport Processes

Anderson, M. A. and P. M. Bertsch. 1993. Electrophoretic mobility and apparent particle size of kaolinite and bentonite within pure and mixed suspensions. *Soil Sci. Soc. Am. J.* (In Press).

Anderson, M. A., P. M. Bertsch, and L. W. Zelamy. 1993. Multicomponent transport of metals through soil subjected to coal pile runoff under steady saturated flow. Pages 137-164 in R. P. Keffer and K. S. Sajwan (eds.) *Trace Elements in Coal and Coal Combustion Residues*. Lewis Publ. Chelsea, MI. (In Press).

Dooskey, M. G. and P. M. Bertsch. Forest sources and pathways of organic matter transport to a blackwater stream: A hydrologic approach. *Biogeochemistry*. (In Press).

Herbert, B. E., P. M. Bertsch, and J. M. Novak. 1993. Pyrene sorption by water soluble organic carbon. *Environ. Sci. Technol.* 27:398-403.

Kaplan, D., P. M. Bertsch, D. C. Adriano, and W. P. Miller. 1993. Soil-borne mobile colloids as influenced by water flow and organic carbon. *Environ. Sci. Technol.* 27:1193-1200.

Novak, J. M., P. M. Bertsch, and G. L. Mills. 1992. Carbon-13 nuclear magnetic resonance spectra of soil water-soluble organic carbon. *J. Environ. Qual.* 21:537-539.

Shann, J. R. and P. M. Bertsch. 1993. Differential cultivar response to hydroxy-polynuclear aluminum complexes. *Soil Sci. Soc. Am. J.* 57:116-120.

Wilkinson, K. W., P. M. Bertsch, C. Jago, and P. G. C. Campbell. 1993. Surface complexation of Al on isolated fish gill cells. *Environ. Sci. Technol.* 27:1132-1138.

F.4. METAL TOXICOLOGY

Metal Toxicity

M. C. Newman

This program began with a study of mercury release from the Effluent Treatment Facility (ETF) but has subsequently expanded to consider mercury in other areas and other metals. At present, it includes a regional survey of mercury bioaccumulation in a sentinel species (the mosquitofish, *Gambusia holbrooki*) and bioaccumulation modeling for SRS-pertinent pollutants in this same fish species. It will continue to be expanded to other sites, species and contaminants as the needs of SRS managers change.

Initially, this research was developed to provide information for assessing ecological effects of (ETF) discharges into Upper Three Runs Creek. Pre- and post-ETF operation monitoring of mercury bioaccumulation in a sentinel fish, the dusky shiner (*Notropis cummingiae*), was conducted in Upper Three Runs Creek. Studies of biomarkers of population-level response to mercury in the mosquitofish also were initiated. In response to SRS needs, the program was expanded in 1992 to monitor off-site and on-site concentrations of mercury in mosquitofish.

Comparison of dusky shiner tissue mercury concentrations before and after ETF operation showed no significant effect of ETF discharge. Concentrations of mercury in fish sampled above, at, and below the ETF discharge also suggested no effect of operations on whole body concentrations.

The biochemical underpinnings of differential tolerance of mosquitofish genotypes continue to be examined. A consistent, differential tolerance to mercury was found for genotypes at a glucose phosphate isomerase locus (PGI-2). This PGI-2 effect is consistent with a growing number of studies demonstrating correlations between a wide range of measures of individual fitness with PGI genotype. Effects were linked to glycolytic flux by examining metabolite pools in fish under mercury stress. In vitro enzyme inactivation experiments suggested that this shift was not a consequence of differential allozyme inactivation by mercury as is commonly believed in such studies.

Experiments in which mosquitofish were exposed for several months to low concentrations of mercury also have been completed. Selection component analysis of these mesocosm populations suggested that low levels of mercury also influence female sexual selection (PGI-2 locus). A three-year, preliminary study with lower mercury concentrations has been recently completed and results reinforce this PGI-2 effect on sexual selection. Preparations are being made for a more extensive, three-year exposure with annual sampling and additional replicates. Restocking of eight, 7250-liter mesocosms will be completed in October 1993. Treatments were added that contained Par Pond sediments in order to assess the effect of associated mercury on mosquitofish populations. The bioaccumulation of mercury also will be determined.

Mosquitofish are being used to monitor mercury bioaccumulation in offsite and onsite aquatic systems. Statistical estimates of appropriate sample size (minimum number of individuals pooled per sample, number of pooled samples per site) are finished. Five to seven pooled samples of such a size as to bring measured mercury concentrations above the limit of quantitation have been taken from more than 20 sites to date. Analysis of these and additional samples taken into the fall of 1993 will be combined with a completed literature review and the resulting report sent to DOE in the winter of 1993.

Pending DOE approval, a workshop, "Quantitative Ecotoxicology: A Hierarchical Approach," will bring together 12 world experts in Aiken (Houndslake facility) in June of 1994. The resulting book and interactions with SRS personnel will greatly facilitate SRS data analysis and provide visibility to DOE-funded research efforts.

Recent Publications: Metal Toxicology

- Beason, W., J. Alberts, H. Allen, C. Hunt, and M. C. Newman. Bioavailability of metals in aquatic environments. (Invited summary chapter in SETAC Workshop, A Mechanistic Understanding of Bioavailability: Physical-Chemical Interactions). (In Press).
- Heagler, M. G., M. C. Newman, M. Mulvey, and P. M. Dixon. 1993. Allotype genotypes in mosquitofish, *Gambusia holbrooki*, during mercury exposure: Temporal stability, concentration effects and field verification. *Environ. Tox. Chem.* 12:385-395.
- Kramer, V. J., M. C. Newman, and G. R. Ullrich. 1992. Changes in concentrations of glycolysis and Krebs cycle metabolites in mosquitofish, *Gambusia holbrooki*, induced by mercuric chloride and starvation. *Environ. Bio. Fishes* 34:315-320.
- Kramer, V. J. and M. C. Newman. Inhibition of glucose phosphate isomerase allotypes of the mosquitofish, *Gambusia holbrooki*, by mercury. *Environ. Tox. Chem.* (In Press).
- Newman, M. C. 1993. Regression analysis of log-transformed data: Statistical bias and its correction. *Environ. Tox. Chem.* 12:1129-1133.
- Newman, M. C. 1992. Zinc accumulation kinetics in mosquitofish: a clarification. *Aquat. Tox.* 24:153-156.
- Newman, M. C. and M. Alpin. 1992. Enhancement of toxicity test data interpretation and prediction of ecological risk with survival time modeling. *Aquat. Tox.* 23:85-Four Mile Creek.
- Newman, M. C. and C. Jago. Inorganic ligands and the bioavailability of metals in aquatic environments. (Invited Chapter in SETAC Workshop, A Mechanistic Understanding of Bioavailability: Physical-Chemical Interactions). (In Press).
- Newman, M. C., M. M. Kekiak, and S. M. Doggett. Quantifying animal size effects on toxicity: A general approach. *Aquat. Tox.* (In Press).

G. BIODIVERSITY ON THE SRS

Results from the biodiversity program will provide information for the development of strategies and options for land managers at SRS and similar ecosystems to enhance biological diversity while using forest resources. The program addresses short- and long-term effects of management options on the diversity of plant and animal life. This cooperative research, unique in combining the talents and resources of federal agencies, industry, and academia, will allow the Department of Energy to manage the resources of the SRS in an environmentally sound manner, recognizing current and anticipated regulatory requirements.

G.1. BIODIVERSITY

Deforestation in the Region of the Savannah River Site

J. E. Pinder, III

The deforestation of natural areas is a principal factor in the extinction of plant and animal species and the reduction of biodiversity on a global scale. This is not just related to the destruction of rainforests as is clearly demonstrated by the controversy concerning the effects of cutting old-growth forests in the Pacific Northwest on habitat for the spotted owl and yew trees. Besides the general reduction in forest habitat associated with cutting, deforestation leads to the fragmentation of forest land into relatively small and isolated patches that have reduced ability to support forest species.

Although deforestation would seem to have little relevance to the largely agricultural region surrounding the SRS, it must be remembered that most of the natural flora and fauna are species of the forest or the forest edge. Most of the now extinct species of the South, such as the ivory-billed woodpecker, were those that required large, continuous areas of forest. Many of the endangered or threatened species, such as the red-cockaded woodpecker, also require large expanses of forest, especially forests of older, larger trees. Because the occurrence, persistence, and distribution of forested habitats greatly affects the biodiversity of the region, it is important to consider the fates of natural and semi-natural forested habitats around the SRS when making decisions concerning land and habitat management on the SRS.

To quantify changes in the quantity and distributions of forested habitats in the area around the SRS, SREL has been using Landsat multispectral satellite images (MSS) to map changes in the distribution of pine and hardwood forests in a 100 X 100 km area centered on the SRS. The MSS images allow mapping to a resolution of one ha (i.e., 100 X 100 m). A library of MSS images has been compiled for the years of 1974 through 1991, and changes in forested areas are measured by comparing forest distributions among years. Analyses of changes in pine forest distribution are in progress and have been largely completed for the period from 1974 through 1988.

The analyses for pine forests have indicated a dynamic landscape with rapid, widespread changes. In 1974, pine forests covered approximately 45% of the area. This percentage includes the pine forests of the SRS. From 1974 to 1988 about 47% of the pines were cut. The rate of cutting was fairly constant at about 3.3% per year or roughly 15000 ha per year. At this rate, all the pine forests may be expected to be cut by 2010.

Regeneration of pine forests has occurred on only about 50% of the cut area. Much of this regeneration has occurred because of active forest management on the SRS or on other large, managed tracts. The lack of pine regeneration on other areas may stem from conversion of the land to urban, industrial or residential use, or the absence of forest management on private land. Whatever the explanation, approximately 25% of the pine forest present in 1974 was lost by 1988.

As would be expected from the rate of cutting, the area that has remained in pine has been subdivided into mostly small, fragmented stands. Within the 100 x 100 km area, there are about 4,200 stands of five ha or larger. The median stand size is about 15 ha. There are 250 stands of 100 ha or more and only ten stands of 1,000 ha or more. Thus, less than 12% of the area is in unfragmented, continuous pine forest. The largest stand of continuous pine forest is 39,000 ha. It includes most of the SRS as well as forests in the valley of Upper Three Runs Creek and accounts for more than 30% of the unfragmented continuous pine forests.

The pattern of forest cutting in the surrounding area is consistent with other data on the ownership of forested land in the South. In contrast to the western United States, where many large forests are publicly owned, the majority of the southern forest land is held in small (less than 40 ha), privately-owned patches. Less than 10% of the southern forest land is publicly owned. These ownership proportions are similar to the proportions for fragmented and continuous stands in the SRS region.

The analysis of pine forest dynamics will be continued through 1991, and similar analyses are being performed for hardwood forests. Hardwood forests are expected to show a less dynamic pattern because the market for and management of hardwoods is considerably less than that for pines.

Effects of Land Management Practices on Forest Biodiversity

D. W. Imm and K. W. McLeod

During FY93, the biodiversity program concentrated on four research areas: 1) sandhills post-burn recovery; 2) tornado site recovery; 3) timber compartment manipulation; and 4) Set-Aside slope diversity. Each project, reviewed below, illustrates how passive or active land management alters vascular plant diversity.

Post-Burn Recovery in Sandhills Vegetation

Sandhills communities have a mosaic of ground cover vegetation. Variation in ground cover composition is related to canopy cover and light attenuation, and reflects differences in soil fertility and litter depth. Further, recruitment of seedlings of tree species differs among ground cover types. These relationships suggest that site physical environment and canopy cover influence development of ground cover, which, in turn, influences recruitment and survival of canopy species.

We examined the effect of time since burning on community structure, species composition, and changes in biodiversity. Parts of the research site, the Sandhills Set-Aside, were winter-burnt in 1981 and 1993 or summer burnt in 1981. Before burning, studies were initiated to consider the impact of fire on plant spatial arrangements.

Two studies considered the role of ericaceous shrub patches and their influence on microsite conditions and seedling recruitment. Ericaceous patches were found to have higher soil organic matter, nutrient concentrations, and soil moisture, and to be more favorable sites for seedling establishment. Two experiments examined differences in seedling regeneration relative to microhabitat differences. In the first, some patches were burned and others were protected from fire. We found that fire removed many submesic woody species, but promoted regeneration of typical sandhills species. The second experiment considered the impact of biomass removal and nutrient amendment on seedling regeneration in unburned plots. We found that removing litter and ground cover promoted release of xeric oaks and ericads; however, the number of new individuals declined over time. Fertilizer additions increased seedling numbers during the first year of recovery.

A third study considered spatial affinities of ground cover types and seedling distributions prior to and following a controlled winter burn. This research revealed that spatial arrangements were disrupted by fire. Pre-existing ground cover patches became loosely clustered to randomly dispersed. Tree seedling survival and post-fire distributions were related to ground temperatures

and juxtaposition to specific canopy species. Seedlings near canopy-sized longleaf pine had much lower survival than those near canopy-sized xeric oaks. Further, survivorship of arboreal species was species and size specific.

From these three studies we concluded that fire disrupts spatial arrangements. Plant response to fire is species-specific at both the canopy and ground-cover level. Further analyses over the next few years should reveal how ground cover patches are re-established, and what resource conditions favor specific ground cover patch types.

Recovery in a Bottomland Hardwoods Community Following a Tornado

The tornado recovery site is a bottomland hardwoods system adjacent to the Savannah River Swamp. This area was devastated by a tornado (September 1989) that left more than two-thirds of the mature trees either uprooted or severely damaged. Salvageable timber was removed from a portion of the damaged area; the remainder of the area was left intact. Permanent plots were set up in the salvaged and unsalvaged areas to study natural recovery. Before harvest of the salvaged areas, trees were sampled to determine forest composition and structure prior to tornado damage. After harvest, plots were sampled at two (1991) and four (1993) years post disturbance.

After four years (1993), the unsalvaged area had 27 species of tree sized individuals, and 34 tree species of sprouts and seedlings. In contrast, the salvaged area was covered with a nearly uniform canopy of perennial grasses and forbs underlain by wind dispersed tree species.

After two years of recovery, 16 seedling and sprout species were present in the salvaged site; by the fourth year four tree species were added. The salvaged area had nearly uniform light and greater soil disruption caused by salvage operations.

Effects of Management at the Timber Compartment Level

This study examined the effects of differing management strategies on biodiversity at the timber compartment level. We selected two adjacent timber compartments (TC32 and TC33) that have slightly different management goals, and compared patterns of species diversity within each relative to management and microsite conditions. Sampling was focused on vegetation and microsite conditions at permanently staked plots arranged in an equidistant grid across each of the timber compartments. Permanent plot sampling was designed to yield baseline diversity and compositional information, which could be used to develop management approaches to increase sustainable biodiversity.

During 1993, sampling was focused on determining baseline compositional and environmental data for each permanent plot (87 positions X 4 plots each) in TC32. TC33 has been sampled in a similar manner in 1992. Eleven basic vegetation types were found: 1) young loblolly pine; 2) mature loblolly pine; 3) thinned loblolly pine; 4) mature longleaf pine; 5) young planted longleaf pine; 6) naturally established pine mixtures; 7) xeric oak-pine mixtures; 8) mesic oak-pine mixtures; 9) hardwood slopes; 10) stream and seep hardwood swamps; and 11) riverine swamps.

The presence of each vegetation type was found to depend upon either management activities or moisture conditions. Species composition within each vegetation type depended upon environmental factors such as moisture relations, soil structure and fertility, topography, and light attenuation. Herb species diversity at small scales was greater in pine systems than in hardwood systems. However, with increasing plot size, species richness increases more

rapidly in the hardwood areas. At large scales, hardwood systems were much more diverse than the pine dominated systems. These vegetation patterns reflect greater light attenuation in the pine system and greater resource heterogeneity in the hardwood system.

Direct relationships and species turnover patterns between environmental conditions and plot composition were stronger in the hardwood systems. Therefore, managed pine systems have fewer occurrences of site-specific species existing across natural gradients than the hardwood systems. This suggests that uniform site preparation may disrupt species-environment continua.

Diversity of Within the Upper Three Runs Cree Forested Set-Aside Slopes

Set-Aside hardwood slopes serve an important function in maintaining diversity on the SRS because they function as refugia for species intolerant of disturbances such as fire and timber harvest. Additionally, they provide habitat for many faunal species. In general, plant species richness over a large area is promoted by uneven forest age structure, the existence of light gaps, and steep environmental gradients such as occur on slopes. To address patterns of species richness and diversity along hardwood slopes, we sampled 16 areas within the Upper Three Runs Creek Set-Aside corridor. Within each sloped area, three belt transects were positioned from the ridge to the slope bottom. Vegetation and a wide array of environmental attributes were sampled in each plot. Composition and diversity patterns were then determined relative to the environment, topography, and location of each sloped area.

We determined that a wide array of associations existed, and that most were strongly correlated with particular topographic or environmental attributes. The most prevalent canopy associations were: 1) scrub oak-hickory-pine; 2) white oak-mockernut hickory-southern red oak; 3) northern red oak-pignut hickory-mixed hardwoods; 4) beech-holly-laurel oak; 5) black walnut-mulberry-basswood; and 6) sweetgum-red bay-loblolly pine-mixed hardwoods. For each canopy association a ground cover association also existed. Because of the loose association of species within these defined community types, direct gradient relationships between plant species and their environment were determined. Topography, light, moisture, fertility, and soil structure all play important roles in determining forest composition.

This study revealed that buffers between hardwood slopes and pine-managed areas influence slope forest composition. Compared with those away from pine managed areas, slopes near pine managed areas had greater seedling densities and basal areas of loblolly pine, sweetgum, and water oak near the ridge. This pattern is likely caused by greater seed rain from adjacent areas for these species (loblolly pine, sweetgum, water oak) during the past several years.

Herpetofaunal Biodiversity Studies on the SRS

J. W. Gibbons and B. W. Grant

The assertion that we are losing biodiversity on a global scale as a consequence of habitat destruction goes uncontested among most biologists. Our long-term objective is to develop and implement field techniques to enhance or restore herpetofaunal biological diversity within a managed landscape. The SRS is ideal for this research because of its large size and habitat diversity, ample availability of human and material resources for labor- and time-intensive studies, and the extensive database already available on resident populations of plant and animal

taxa (including herpetofauna) for integration with the present study. The specific objectives of our herpetofaunal biodiversity research program are:

- (1) To develop standardized censusing techniques to estimate herpetofaunal relative abundance and various measures of biodiversity.
- (2) To quantify herpetofaunal population variations that result from processes other than management (i.e., daily or seasonal variation, chaotic population fluctuation or environmental variation, and habitat differences).

We met our first objective through the development of the coverboard technique. We have published a book chapter that encompassed all coverboard data collected before August 1990 (2,876 reptiles and amphibians beneath 51,006 coverboard during 444 site checks), and analyzed sources of variation in herpetofaunal encounter rates because of the character of these taxa (e.g. wet vs. dry skin, body size), environmental variables (hydrothermal microclimate conditions beneath coverboard), and inherent biases of the coverboard technique (e.g., coverboard age and placement). We are continuing to census additional arrays, some that have been censused since the late 1980s, and have established arrays at selected wetland habitats. To meet the third objective, we will continue to establish new coverboard arrays in habitats under different management regimes.

Comparative and experimental long-term data from our studies will suggest mechanisms leading to enhanced or reduced herpetofaunal biodiversity within managed habitats. These data will give us the unique opportunity to elucidate steps to mitigate the effects of various standard management practices on herpetofaunal biodiversity, and will provide the means for managers to fulfill congressional ecological mandates subject to economic constraints on land use.

Stream Fish Community Biodiversity, Species Interactions and Mutualisms, and Populational Diversity

G.K. Meffe and D.E. Fletcher

Stream Fish Community Biodiversity

Emphasis in this program is on the effects of beaver dams on stream fishes. Beaver dam construction, maintenance, and eventual decline and destruction are important components of local and stream-wide composition of fish communities. Preliminary studies in summer and fall of 1992 were conducted to begin sampling of selected beaver dams and associated streams. Also, incorporation of GIS began in winter and spring of 1993. This information will permit identification of former and current dams, including a historical perspective of dam dynamics. This summer we began intense field sampling of fish communities, and measurement of habitat changes due to dams will commence.

Species Interactions and Mutualisms

Initial observations of the nest association of dusky shiners (*Notropis cummingsae*) and redbreast sunfish (*Lepomis auritus*) on the SRS were published in Copeia in early 1993.

Experiments were conducted in replicate cattle tanks to address the following questions: 1) Is this nest association a parasitic relationship? 2) Is the association facultative or obligatory for dusky shiners? 3) Do dusky shiners preferentially select sunfish larvae while feeding in nests? Results indicate that this is a parasitic relationship, and dusky shiners are an obligate nest associate of the redbreast sunfish. A new cattle tank facility, much improved over the existing facility, was constructed at the Aquatic Ecology Laboratory in spring 1993, and will allow more sophisticated experimentation with these and other fishes. New experiments are beginning as of this writing.

Populational Differences

Quarterly collections continue to be made of mosquitofish (*Gambusia affinis*) across ten sites on the SRS to compare life history patterns in a diversity of habitats. Reproduction, body shape, and lipid storage dynamics are being compared across the ten sites. Preliminary data analyses are being conducted. Thirteen sites (including many of the ten regularly sampled sites) were used in a test of a theory on overwinter lipid storage, and a manuscript will soon be submitted. A second paper on comparative lipid use in mosquitofish of Pond C and Risher Pond is in press (Copeia), and a third paper, on a laboratory experiment to test details of lipid use in reproduction, is also in press (Canadian Journal of Fisheries and Aquatic Sciences). We also conducted studies on patterns of cannibalism in mosquitofish at several SRS sites, and that paper is in press in Copeia.

Recent Publications: Biodiversity

- Bertram, T. A. and A. E. Cook. Comparing GPS with large scale maps and applications to ecological research. *Journal. GPS World*. (In Press).
- Cook, A. E. and J. E. Pinder III. Relative accuracy of rectifications using coordinates determined from maps and global positioning systems. *Photogram. Engin. Rem. Sens.* (In Press).
- Fletcher, D. E. 1993. Nest association of dusky shiners (*Notropis cummingsae*) and redbreast sunfish (*Lepomis auritus*), a potentially parasitic relationship. *Copeia* 1993:159-167.
- Grant, B. W., A. D. Tucker, J. E. Lovich, A. M. Mills, P. M. Dixon, and J. W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pages 379-403 *in*: D. R. McCullough and R. H. Barrett (eds.). *Wildlife 2001: Populations*. Elsevier Science Publishers Ltd., New York, NY.
- Meffe, G. K. and F. F. Snelson, Jr. Annual lipid cycle in eastern mosquitofish (*Gambusia holbrooki*: Poeciliidae) from South Carolina. *Copeia*. (In Press).
- Meffe, G. K. and F. F. Snelson, Jr. Lipid dynamics during reproduction in two livebearing fishes, *Gambusia holbrooki* and *Poecilia latipinna*. *Canadian. Journal. Fisheries Aquatic Sciences*, (In Press).
- Moorhead, K. K. and A. E. Cook. 1992. A comparison of hydric soils, wetlands, and land use in Coastal North Carolina. *Wetlands* 12:99-105.
- Moorhead, K. K. 1992. Wetland resources of coastal North Carolina. *Wetlands* 12:184-191.

Recent Publications: Biodiversity (Cont'd)

- Nesbit, D. H. and G. K. Meffe. Cannibalism frequencies in wild populations of eastern mosquitofish (*Gambusia holbrooki*: Poeciliidae) in South Carolina. *Copeia*, (In Press).
- Schupp, E. W. 1992. The Janzen-Connell model for tropical tree diversity: Population implications and the importance of spatial scale. *Am. Nat.* 140:5 26-530.
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G.2. DOE SET-ASIDES

DOE Research Set-Aside Areas

C. E. Davis

The purpose of the Set-Aside program is to establish lands on the Savannah River Site (SRS) that represent unique and natural habitats of the region, to offer protection to rare, threatened, and endangered biota that inhabit these areas, and to provide sites on the SRS that are conducive to long-term ecological research. In addition, these undisturbed natural areas serve as control sites for evaluating impacts from SRS site operations and intensive forest management activities. Through the Set-Aside program, the protection and preservation of these areas will not only aid in sustaining a high degree of biological diversity on the site, but also will fulfill the Department of Energy's (DOE) need to maintain the SRS as a National Environmental Research Park (NERP).

With field boundary line establishment complete for the set-aside areas, the Savannah River Ecology Laboratory (SREL) developed a computer-based Geographical Information System (GIS) data layer describing the set-aside boundaries. This GIS boundary line coverage was created primarily to generate maps and area statistics for report preparation, and to give positional coordinate values to the boundary lines. The inclusion of these line coordinates into the Automated Site Use System (ASUS) for site use coordination was necessary to reduce encroachment conflicts on the set-aside areas. In addition, the inclusion of this GIS coverage into the SRS sitewide GIS database ensures the set-aside areas will be incorporated into the Site Development Plan and Current/Future Use Site Map for land use and management planning activities. It was determined from the coverage that the area for the set-asides totalled about 14,288 acres (5782 ha), and that boundary length totalled 284 miles (427 km) of posted line. A set-aside map was composed from the SETASIDE Arc/Info coverage (Version 1) and distributed to DOE, Savannah River Forest Station (SRFS), and Westinghouse.

All Carolina bay set-asides were recommended for inclusion into the Environmental Protection Agency's (EPA) Advanced Identification (ADID) Project. The goal of the Carolina Bay ADID Project in South Carolina is to enhance the protection of these wetland ecosystems by identifying the most important examples that remain in the state. SREL was asked to support the ADID project by identifying SRS Carolina bays that may warrant inclusion. SREL developed cooperative arrangements with the SRFS to coordinate the management of nuisance animals in Set-Asides, to verify set-aside and timber stand boundary line coincidence with GIS coverage, to develop GIS coverage for sensitive plant populations in set-asides and the SRS, and to be involved in pre-planning activities for prescribed burning programs. Copies of aerial photos with annotated boundary lines of the set-asides were provided to the SRFS.

A NERP document containing floral, faunal, and soils information for all 30 set-aside areas is in preparation and will be submitted for review and comments to DOE by the end of FY93. Reference files are being developed for each set-aside area, including photos, maps, and all publications and research efforts associated with each set-aside. In addition, a coded data archiving system is being developed for easy data retrieval.

The Set-Aside program solicited proposals for small research projects in set-aside areas to include floral, faunal, and geochemical-based projects. To date, two projects have received funding: a herpetofaunal survey in Carolina bays, and a study of harvester ant dispersal patterns. SREL continued numerous on-going studies in set-asides and initiated new research to include studies on stream invertebrates, population dynamics of flying squirrels, and the habitat

use/water finding abilities of turtles in Carolina bays.

Future accomplishments for the set-aside program will focus on completion of the NERP document on set-aside areas, and evaluating other SRS GIS coverage that include set-asides boundaries. Inventories of biotic communities of the individual set-aside areas will be partially based on the review of previous and current studies on the set-asides. The sensitive plant survey being conducted by the SRFS will be incorporated into the set-aside GIS. These inventories will be further developed using remote sensing and field techniques.

Recent Publications: DOE Set-Asides

Collins, B. S. and G. R. Wein. 1993. Understory vines: Distribution and relation to environment on a southern mixed hardwood site. *Bull. Torrey Bot. Club* 120:38-44.

Davis, C. E., A. E. Cook, and J. B. May. 1993. GIS data set of Set-Aside boundary lines - file SETASIDE (Version 1). SREL Metadata for GIS. Savannah River Ecology Laboratory, Aiken, S. C.

Lide, R. F. and C. E. Davis. 1993. EPA Advanced Identification (ADID) Project: Carolina Bays at the Savannah River Site. SREL-45/UC-66e. Savannah River Ecology Laboratory, Aiken, S.C. 15 pp.

H. ENVIRONMENTAL TOXICOLOGY

The objective of this program is to continue and expand investigations of toxic effects (including genotoxicity) on organisms exposed to contaminated or polluted habitats on the SRS. Studies on genotoxic effects will include development of new biochemical, histological and ultrastructural indices to detect damage to cell nuclei, and refinement of flow cytometric methods previously employed. Sublethal stresses from environmental contaminants will be assessed in selected natural populations by physiological and histological techniques. Additionally, "sentinel species" surveys will be conducted, in which animals are placed in contaminated or polluted sites and monitored using the above indices for selected periods of time. Laboratory exposures to simulate environmental conditions also will be performed. These studies will provide important information on: (1) potential sources of sublethal stresses and genetic damage, including identification of sites where contamination is producing measurable effects, (2) re-evaluation of levels of exposure to radiation or other pollutants considered non-hazardous, and (3) effectiveness of mitigation efforts.

ENVIRONMENTAL TOXICOLOGY

Genotoxicology Studies

R. K. Chesser, C. H. Jagoe, M. H. Smith, and I. L. Brisbin, Jr.

The purpose of this research is to develop and test biomarkers of long-term exposure of organisms to low levels of radionuclides and other pollutants. One promising biomarker involves detection of damage to DNA resulting from exposure to environmental contaminants. Flow cytometry, a method to detect such damage, allows large numbers of organisms to be screened for changes in cell DNA content. Before screening SRS fish populations using this method, we completed a series of experiments to develop quality control and quality assurance procedures, and to verify the sample handling, preparation, and analysis protocols. This research examined freezing effects, sample handling, and variation over time on fish blood DNA profiles, and incorporated an internal standard to allow correction for instrument error. A manuscript detailing this work is under revision. In 1992 and 1993, more than 2,600 largemouth bass from Pond B, Pond C, Par Pond, L-Lake and the Steel Creek Swamp on the SRS, and "control" locations off-site in Georgia and South Carolina, were captured, and blood samples were obtained. Most fish were released unharmed, but some were sacrificed for future analysis of contaminant body burdens. Analyses of the blood samples by flow cytometry has been completed, and the data are being analyzed using a variety of statistical methods. We plan to obtain more off-site control samples for comparative purposes, and produce a manuscript based on this research later this year.

Methods to examine blood cell nuclei for abnormalities by light and scanning electron microscopy have been developed and will be applied to detect DNA lesions. The normal structure of blood cell nuclei in several species of fish was surveyed using these methods to provide a baseline for comparison with contaminant-exposed fish. This work has been accepted for presentation at an international meeting later this year. We are routinely using an alkaline unwinding assay to measure breakage of DNA strands in response to contaminant exposure. Tissues from largemouth bass gill, liver, and red blood cells yielded sufficient DNA concentrations for analyses of DNA damages to be performed. Fish collected from locations on and off the SRS are being analyzed to determine background strand break levels. Additionally, laboratory experiments involving exposure to agents known to cause DNA damage have been conducted. These experiments will confirm the utility of the various techniques in measuring DNA damage, and assist in interpreting the etiology of any damage detected. We also developed blood leukocyte culture techniques for largemouth bass. Blood cultures will allow us to examine chromosomes in dividing cells after pollutant exposure, and serve as an *in vitro* model to study effects of various contaminant dosages. Another method of determination of ATP-ase activity was developed at SREL this summer and will permit determination of chemical toxicity to cells that may or may not involve genetic damage. Two manuscripts demonstrating the utility of our techniques and quality assurance controls have been submitted. A large study of the relationship between mercury concentrations and DNA damage in fish is nearing completion. The ecological toxicology program has now reached the point in its technical development at SREL that manuscripts will be developed on a regular basis.

To better understand the relationship between environmental contamination and DNA damage, we collected samples within and outside of the 10-kilometer and 30-kilometer exclusion zones surrounding the Chernobyl, Nuclear Power Plant in Ukraine. Samples were taken from a total of 17 sites: nine from ponds and lakes outside the zone, one from within the 30-kilometer zone, and seven from within the ten kilometer zone. Imported catfish from the reactor cooling pond were analyzed (N=38), and several species of snails and fish were collected from a gradient of high to low levels of radioactive contamination. Results thus far show that genetic damage is visible, but quantitative values await completion of laboratory analyses. These research endeavors are very promising and have received recognition from scientists and government agencies worldwide.

Changes in Fish Assemblages in a Reactor Cooling Reservoir in Relation to Reactor Operation

J. D. Congdon and R. U. Fischer

Pond C is part of the Par Pond reservoir system on the SRS. It has received chronic and acute impact from heated effluent from operation of P-Reactor. In addition, Pond C has had water levels reduced because of the drawdown of the Par Pond system. We have monitored the fish assemblage in Pond C from approximately two years before reactor shutdown to present. Fish samples were collected using an electroshocking boat during four distinct periods, 1) reactor operation, 2) reactor shutdown, 3) six months after draw down, and 4) one year or greater after draw down. A total of seventeen species of fish were caught, and 2,800 individuals were marked during the four collection periods. The two species of numerically dominant fish (excluding mosquitofish) during all four periods were bass, which accounted for 27 - 61% of the assemblage, and bluegill, which accounted for 22 - 41%. The number of species increased from five dominant species during reactor operation to about 12 dominant species during the period following reactor operation. The number of dominant species in each sample has remained stable at about 12 during the remaining sampling periods. Some of the new dominant species entering the pond during the past three sampling periods were yellow perch, black crapple, redbreast sunfish, warmouth, and lake chub sucker, which are more typical of fish assemblages in normothermic ponds. We will continue systematic collections on Pond C to determine if or when the fish community of Pond C comes to a relatively stable equilibrium in the number of species and numerical dominance.

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

J. D. Congdon, R.U. Fischer, and R. G. Nagle

Coal powered plants produce electricity for the SRS, and the resulting coal fly ash is stored in basins on the site. Although fly ash is not considered a hazardous waste, some

constituents of the ash may be of environmental concern. Some metals and other contaminants leach into aquatic habitats adjacent to coal piles. The contaminants subsequently may be taken up by plants and animals. Bioaccumulation of some trace elements may cause sub-lethal effects that are expressed at both the individual and population levels. At the individual level, organisms with chronic exposure to pollutants may accumulate metals at levels that, 1) cause death, 2) disrupt physiological processes, or 3) impair reproduction. In addition, accumulation of metals may also directly affect offspring during development or indirectly through genetic damage to parents. A combination of changes in mortality and reproductive success of individuals in impacted populations results in changes in population dynamics in the short term, and possibly life-history changes in response to chronic exposure. We conducted a pilot study to determine if turtles that reside in the aquatic areas near the coal ash piles had higher levels of arsenic, cadmium, and chromium in soma and reproductive tissue, compared to levels found at a reference site (Kathwood area). We found that, compared to turtles from Kathwood area, turtles from the D-area ash basin area had elevated levels of arsenic, cadmium, and chromium in their livers and muscle tissue, and elevated levels of arsenic and cadmium, and to a lesser degree chromium, in reproductive tissue. In addition, the proportion of reproductive females captured at the ash basin area (4%) was substantially reduced compared to the Kathwood site (44%).

We plan to continue collecting turtles and additional aquatic organisms to determine the levels of contaminant uptake in aquatic organisms in or near the ash basin. Additionally we will examine the effects of contaminants on the survival and growth of selected offspring.

I. ENVIRONMENTAL OUTREACH AND EDUCATION

This program is designed to educate the public about ecological research and environmental issues, with emphasis on SREL and the SRS. This is done through communication of information to the popular press, including newspapers, magazines, and various electronic media, and through oral presentations to schools, civic groups, garden clubs and other organizations interested in environmental issues. Efforts also include participation in exhibits that serve the goals of environmental education and tours of SREL and the SRS that emphasize ecological research programs and environmental initiatives. Various student research participation and teacher training programs at SREL are also being organized and operated as part of this effort.

ENVIRONMENTAL OUTREACH AND EDUCATION

J. W. Gibbons

This program is designed to educate the public about ecological research and environmental issues, with emphasis on SREL and the SRS. This is done through communication of information to the popular press, including newspapers, magazines, and various electronic media, and through oral presentations to schools, civic groups, garden clubs, and other organizations interested in environmental issues. Efforts also include participation in exhibits that serve the goals of environmental education and through tours of SREL and field sites on the SRS that emphasize ecological research programs and environmental initiatives. Various student research participation and teacher training programs at SREL also are being organized and operated as part of this effort.

A new Division of Environmental Outreach and Education was created at SREL during the 1991 fiscal year. The new program is designed to enhance SREL's overall mission of acquiring and communicating environmental knowledge and addresses DOE's current focus on environmental issues.

While the program has existed informally for years, the Environmental Outreach and Education Division now presents talks to local schools, civic groups, and other organizations averaging about four presentations per week and approximately two tours every three weeks. 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 182 lectures, 45 tours and ten exhibits. One exhibit the Palmetto Sportsmen's Classic in Columbia, S.C., was attended by an estimated 72,000 people.

Most of the lectures and presentations have been made at schools, children's camps, civic organizations, and garden clubs. Topics for the presentations have included animal ecology and outdoor safety, plants and wetlands, the environment, conservation, and careers in ecology and research.

The public relations program has included the mailing of news releases to a regular list of about 100 media affiliates and officials of DOE and the University of Georgia. The program has also promoted various research projects through coverage in local and national media, and worked to enhance the laboratory's internal communications. Included among these have been coverage of SREL research in the San Francisco Examiner, Los Angeles Times, and The Christian Science Monitor. This program also has been responsible for planning and organizing special events, including tours for dignitaries and a reptile and amphibian identification workshop for the general public. Ongoing projects include an internal laboratory newsletter published on a monthly basis and an increased number of video projects. An 18-minute general lab video was completed this year. This video has been sent to undergraduate college students as well as local high school and middle schools.

The division has also assumed management responsibilities for the laboratory's education program. In SREL's education program this fiscal year, nearly 70 high school students, undergraduate and graduate students, and pre-college teachers conducted research at SREL.

Many of the participants were from Georgia and South Carolina, but students also were represented from 19 other states.

The undergraduate students, whose education and training have been supported by DOE, were funded in part by a grant of approximately \$50,000 from the National Science Foundation (NSF). During this summer, 12 of the 22 undergraduate students were supported by NSF funding.

Also this summer, SREL participated in a program for pre-college teachers sponsored by Associated Western Universities. Six Teacher Research Associates (TRAC) program participants conducted research at the laboratory. At SREL, the program participants attended seminars, lesson-planning sessions, and weekly discussions on research articles. Participants in this summer program, directed for the laboratory by Dr. Nathaniel B. Frazer, former associate professor and chairman of the biology department at Mercer University in Macon, GA, also could receive five hours of graduate credit from Mercer for their participation.

J. PAR POND DRAWDOWN STUDIES

The Par Pond Reservoir System is a cooling reservoir located on the SRS, where the water level has been maintained at about 210 feet above sea level for more than 30 years. During the summer of 1991, the water level in Par Pond was drawn down approximately 19 feet. This action, ordered by the Department of Energy, was undertaken to reduce the impact of a potential dam failure while assessing the condition of the dam structure and determining if repairs were necessary. Because of this drawdown, potential radiological and ecological impacts had to be determined. Savannah River Ecology Laboratory began monitoring programs on wildlife and fish at Par Pond in July 1991.

ECOLOGICAL EFFECTS OF THE PAR POND DRAWDOWN

Wildlife Studies

I. L. Brisbin Jr. and J. F. Seel

Wildlife research studies initiated in July of 1991 to document the effects of the Par Pond drawdown on native fauna, are proceeding into the 1993 study-season. Night eye-shine censuses of alligators on the Par Pond reservoir are being performed on a monthly basis with about 75 to 100 alligators being counted on each survey. Of the original group of 19 alligators that were radio-collared in 1991 and 1992, two specimens died, both apparently of natural causes. The remaining 17 alligators have been located once every 18 days on the reservoir. Recapture of alligators began in May 1993 for the sole purpose of replacing radio-collars that were expected to experience battery failure in the next few months. As of June 15, 20 alligators had been captured using a snare-set trap baited with fish. Seventeen of these 20 alligators were recaptures, and four were carrying older radio-collar units that were replaced with newer alligator radio-collars. However, three of the 20 captured alligators, none of which were carrying radio-collars, died while trapped in the snares. Two of these were killed by larger aggressive alligators, and one apparently died while struggling against the snare. There are four more alligators with older transmitters whose batteries are due to expire within the next month. The remaining nine transmitters should last until 1994.

Concentrated studies on the movements of these alligators and the effects sex, size and season have on these movements were started in the spring of 1993 and are proceeding. Archiving of alligator data is ongoing.

All previously collected samples from feral hogs and deer now have been analyzed for ¹³⁷Cs concentrations. Fifty feral hog muscle samples and 215 fecal samples were analyzed for radiocesium. Further studies will be done to test a previously established correlation between contamination found in fecal samples and contamination present in the muscle. White-tailed deer muscle samples (N=46) were analyzed from the 1991 deer hunt in compartments directly adjacent to Par Pond. Thirty-one deer muscle samples were analyzed from the 1992 hunt. An analysis of variance indicated a significant increase in the radiocesium content of muscle from deer taken on these hunts between 1991 and 1992, with deer from the hunt compartments near Par Pond having higher levels of contamination than deer from other locations on the SRS.

Sightings of bald eagles and ospreys were recorded for Par Pond. The reservoir was frequented by juveniles as well as adult eagles. Annual systematic census cruises to count wading birds and other avifauna were continued in all major SRS reservoirs through 1993. The results of these censuses now have documented increases in wading bird numbers at the site of the Par Pond drawdown. This is likely a response to a "trophic upsurge" of prey availability caused by elimination of emergent macrophyte cover, similar to that documented by these same surveys several years earlier following the establishment of L-Lake.

Studies now have been initiated using radio-telemetry to determine the movement and behavior of terrestrial turtles (*Terrapene carolina*) inhabiting wooded habitat bordering the CERCLA unit. These studies have shown that some of these turtles move freely into and out of the CERCLA unit and use the now-exposed contaminated mudflats of that area.

Fish Community Structure, Reproductive Changes in Mosquitofish, and Lipid Composition and Cycling in Mosquitofish

G. K. Meffe and S. C. Weeks

Community Sampling

Community samples in Sanctuary Cove, Pond C, were continued this year. Numbers of individuals and species are declining as the system matures and as less water is found in the feeder stream.

Mosquitofish Life History Patterns

Mosquitofish had become rare in Pond C and virtually absent in Par Pond last year. We to obtained small samples from both sites this year and are analyzing them.

Lipid Analysis

We completed a long-term experiment begun in late winter 1992 to examine lipid storage and use in mosquitofish from Pond C, and the genetic basis for such patterns. Results are being analyzed and will provide information on the effects of resource level and genetic constitution upon growth, maturity, and lipid use, caused by controlled mating and rearing procedures employed. A second experiment began in spring 1993 to examine heritability patterns of certain life history traits.

Changes in Fish Assemblages and Reproductive and Whole Body Lipid Cycles of Bluegills

J. D. Congdon and R. U. Fischer

During the periods when we have had access to Par Pond, we have been monitoring the effects of prolonged drawdown on species composition, survival and population sizes of fish. In addition, we have sampled Pond C and Par Pond fish to determine the reproductive state of females and body condition by determining whole body lipids. We have collected and marked 1,282 fish (18 species) from Par Pond and 2,614 from Pond C (17 species). A total of 118 recaptures have been caught in both ponds. The two most dominant species in both ponds are bass and bluegill, which compose about 50% and 20% of the total fish assemblage, respectively in both reservoirs. During the prolonged drawdown period, the number of species in each sample has remained stable at 9 and 12 for Par Pond and Pond C, respectively. However, during the long reactor down period, we have observed a variety of species in both sites disappearing with new species taking their place indicating a community not at equilibrium. We will continue to systematically sample both Par Pond and Pond C to make an accurate assessment of population size and survival.

We also have collected bluegill samples over the past eight months for determination of whole body lipid and reproductive state of fish from both sites. We plan to continue systematic

sampling of bluegill for the next four months to determine the annual lipid and reproductive cycles of bluegills from both ponds.

Trace Metal Content of Fish and Mercury Accumulation in Par Pond Bass

C. H. Jagoe

When the level of Par Pond was lowered, changes in biotic and abiotic conditions occurred. These included increased erosion and sediment resuspension, altered thermal regime, and changes in fish habitat and water chemistry. In addition to radionuclides, the Par Pond system contains mercury and potentially other toxic trace metals. The purpose of this research is to determine if the altered hydrologic conditions in Par Pond have resulted in changes in mercury levels in fish and other biota. This study also will yield information about effects of water chemistry variation in trace metal cycling in reservoir systems.

Samples of largemouth bass have been collected quarterly since December 1991, except for the period during 1992 when access to Par Pond was restricted. The most recent sampling was done in late May and early June 1993. Water samples also were collected semi-monthly from several locations within Par Pond during the periods when access was permitted. Samples of forage fish, plants, and benthic invertebrates also were collected during the past year. Routine collections of water and biological samples have now resumed. Digestion and analysis protocols have been developed and tested, and are being routinely used on biological samples. Mercury analyses have been completed on bass samples collected through mid 1992, and analyses for other trace metals (including Cd and Pb) are under way on subsamples of these. Samples of plant materials, benthic invertebrates and forage fish species have been analyzed and more samples are being collected.

Results of laboratory studies on the effects of mercury (II) on fish gills were presented at an international meeting last fall and attracted considerable interest. A publication based on these studies is in preparation. In another laboratory study, bluegills were exposed to beryllium at two levels of Ph to assess the effects of differences in water chemistry on the toxicity of the metal. Physiological data, including blood chemistry and tissue ion levels, also were collected to study sublethal effects.

Initial development of methods to determine mercury speciation in biological and environmental samples has begun. Speciation will be done by aqueous phase ethylation, gas chromatography and cold-vapor atomic fluorescence spectroscopy techniques. We are acquiring and testing the new instrumentation needed for these analyses. This information will be useful in future mercury budget and cycling studies, and in modelling efforts.

Recent Publication: Par Pond Drawdown Studies

Bildstein, K. L., D. E. Gawlik, D. P. Ferral, I L. Brisbin, Jr. and G. R. Wein. Wading bird use of established and newly created reactor cooling reservoirs at the Savannah River Site, Aiken, South Carolina. USA. *Hydrobiologia*. (In Press)

Brisbin, I. L., Jr., J. M. Benner, L. A. Brandt, R. A. Kennamer, and T. M. Murphy. Longterm population studies of American alligators inhabiting a reservoir: Initial responses to water level drawdown. *In: Proceedings of the Eleventh Working Meeting of the Crocodile Specialist Group. SSC/LUCN. Glan, Switzerland.*

Recent Publication: Par Pond Drawdown Studies (Cont'd)

Brisbin, I. L., Jr. Birds as monitors of radionuclide contamination. *In*: Birds as Monitors of Environmental Change. Chapman and Hall, London. (In Press).

Brisbin, I. L., Jr. Applications of a modified Richards sigmoid model to assess the uptake and effects of environmental contaminants upon birds. *In*: The Population Ecology and Wildlife Toxicology of Agricultural Pesticide Use: A Modeling Initiative for Avian Species. A publication of the Society of Environmental Chemistry and Toxicology. Washington, D.C. (In Press).

L. THEORETICAL ECOLOGY

None of the environmental and ecological data collected on the SRS are precisely accurate. Chance variability affects every measurement. Some of the variation stems from measurement error; some stems from variability among individuals, among sites, and over time. The goal of statistical analysis is twofold: to extract correct conclusions from imprecise data and to quantify our belief in the truth of those conclusions. This research program component will develop and evaluate statistical methods for the analysis of environmental and ecological data.

THEORETICAL ECOLOGY

P. M. Dixon

This program includes two research components. The first studies the theoretical properties of sigmoidal curves, used as statistical models for growth curves and toxicant accumulation curves. The second develops and evaluates statistical methods to estimate trends in ecological communities. The program was not funded during FY93, so no work was done. The questions are still important for many research programs at SREL. Given the funding that is expected in FY94, these questions can begin to be answered.

II. AWARDS AND HONORS

Honors

Dr. Charles M. Lydeard was elected to the honor society Phi Kappa Phi. Dr. Lydeard also won the Student Research Paper Award from Sigma Xi, the Scientific Research Society, for his paper, "Molecules, morphology, and area cladograms: A cladistic and biogeographic analysis of *Gambusia* (Teleostei: Poeciliidae)."

Three members of SREL won the UGA Institute of Ecology's Annual Best Student/Technician Paper. **Evelyn E. Gaiser**, a graduate student at UGA, and Dr. Roger Bachmann of Iowa State University were honored for their paper in Limnology and Oceanography titled, "The ecology and taxonomy of epizoid diatoms on Cladocera." Another UGA graduate student, **John Krenz**, and research technician **David E. Scott** were honored for their co-authored paper titled, "Terrestrial courtship affects mating locations of *Ambystoma opacum*."

Tracy Parker of Aiken, SC and **Rebecca Byrd** of Augusta, GA, participants in last summer's Young Scholars Program at SREL, recently won first and second places, respectively, in the Central Savannah River Area (CSRA) Science Forum for their presentations of research papers based on their work at SREL.

Jeff Seel, a University of South Carolina masters degree student at SREL, won first place in the student competition for his presentation at the Second Annual Carolinas Chapter Meeting of the Society of Environmental Toxicology and Chemistry (SETAC). His presentation, "The effects of potassium on availability of ^{137}Cs to vegetables grown on a contaminated lake bed," was based on research conducted for his under the supervision of Dr. F. Ward Whicker.

Awards

Rebecca S. Yeomans, a University of Georgia masters degree student, received the Best Student Research Award from the Association of Southeastern Biologists. Rebecca won the award for her research paper entitled, "Turtle orientation: Field test of water-finding ability in adult yellow-bellied pond sliders." She also received an honorable mention for the Eugene P. Odum Award, which is given by the Southeastern Chapter of the Ecological Society of America, for the best student paper presented in ecology. Rebecca's research project is supported by DOE and is under the supervision of SREL Senior Research Ecologist Dr. J. Whitfield Gibbons.

Dr. F. Ward Whicker, senior research ecologist, was awarded a ERDA grant for investigations into the distribution and dynamics of radionuclides in ecosystems of the Savannah River Site.

Dr. Sue Clark, assistant research ecologist, was awarded an ERDA to conduct investigations on

the "Source term quantification and factors controlling the geochemistry of contaminants in the F and H area seepage basins." She was also awarded a grant to aid in sponsoring the Fourth International Conference on the Chemistry and Migration Behavior of Actinides and Fission Products in the Geosphere from two funding source, the Commission of European Communities and the International Atomic Energy Agency.

Dr. Tom Hinton, assistant research ecologist, was awarded a grant by Paul Scherrer Institute of Villigen, Switzerland for collaborative research in radioecology.

Dr. Rebecca Shartz, senior research ecologist, received a grant from the Andrew W. Mellon Foundation for her participation in research at the Congaree National Monument titled "The role of hurricanes in structuring forest vegetation."

Drs. J Vaun McArthur and *Harris Martin* received a grant for the investigation of "Microbial ecology of sulfur bacteria in underwater limestone caves" from the PADI Foundation.

Dr. Kenneth McLeod, associate research ecologist, for the third year in row received funding from Savannah River Technology Center to continue research on the restoration of bottomland hardwoods in Fourmile Branch.

Four of SREL researchers, *Drs. Justin Congdon, John Pinder, III, Barbara Taylor, and Philip Dixon* received funding from a grant titled "Comparative risk assessment of climate change and other anthropogenic stressors: Habitat and biological diversity on the Savannah River Site, South Carolina." The grant was awarded by the Environmental Protection Agency. Other co-investigators include *Drs. Ronald Pulliam* and *John B. Dunning, Jr.*, of the University of Georgia and *Brent Danielson* of Iowa State University.

III. EDUCATION PROGRAM PARTICIPANTS

Short-term Graduate Participation Program

Vicky Batson	M.S.	Texas A&M University
Loretta Battaglia	Ph.D.	University of Georgia
Michele Basham	M.S.	Texas A&M University
Matthew Brady	M.S.	Auburn University
Robert Cheney	Ph.D.	University of Georgia
Michael Draney	Ph.D.	University of Georgia
Adrienne Edwards	M.S.	University of Georgia
Evelyn Gaiser	Ph.D.	University of Georgia
Nicholas Haddad	Ph.D.	University of Georgia
Christopher Harrison	Ph.D.	Texas A&M University
Randall Hudson	M.S.	Texas A&M University
Scott Johns	M.S.	Clemson University
Mark Komoroski	Ph.D.	University of Georgia
John Lee	M.S.	University of Georgia
Susan Miller	M.S.	University of Georgia
*Christopher Salice	M.S.	Drexel University
Julian Singer	M.S.	University of Georgia
Julie Weis	Ph.D.	University of Georgia
Dana Winkelman	Ph.D.	University of Georgia

Undergraduate Research Participation Program

Anupa Batra	Bradley University
Sharia Benjamin	Duke University
Russell Bodle	University of South Carolina
Sandy Brundage	Auburn University
Lella Hadj-Chikh	Wilkes University
Avery Groat	University of South Carolina
Evonne Hart	Westmont College
Jennifer Hopper	University of Georgia
Russell Jeffers	Erskine College
Michael Lloyd	Westminster College
Camille McNeely	University of Texas
Ann Osborn	University of South Florida
Russell Prescott	University of South Carolina
Ryan Reardon	Rhodes College
Kerrey Roberto	Hendrix College
Geoffrey Siemering	Pomona College
Kelley Smith	Southeastern Louisiana University
Carrie Thomas	University of Wisconsin
Tywaun Tillman	Furman University
Tracey Tuberville	Furman University
Chris Wheat	Emory University

*These students received a scholarship from the Environmental Restoration and Waste Management Scholarship Program through Oak Ridge Associated Universities.

Visiting Faculty on Sabbatical

Thomas Jensen	Virginia Tech
Diane DeSteven	University of Wisconsin-Milwaukee
Stephen Dobson	Auburn University
Michael Held	St. Peters College

Long-term Graduate Participation Program

Kurt Buhlmann	Ph.D.	University of Georgia
Vincent Burke	Ph.D.	University of Georgia
Sheila Colwell	M.S.	University of Georgia
Michael Floyd	Ph.D.	Clemson University
Katheryn Gubista	Ph.D.	University of Georgia
Frank Hensley	Ph.D.	University of Florida
Karen Kandl	Ph.D.	University of Georgia
John Krenz	Ph.D.	University of Georgia
Vicki Medland	Ph.D.	University of Georgia
Mark Mills	Ph.D.	University of Georgia
Thomas Risch	Ph.D.	Auburn University
Joel Snodgrass	Ph.D.	University of Georgia
Rebecca Yeomans	M.S.	University of Georgia
Christopher Hudson	Ph.D.	University of Georgia

TRAC

George Anderson	Vero Beach Junior High
Daniel Funach	The Alleluia Community School
John Hoon	Hawkins Middle School
Edward Moore	Lake Clifton-Eastern Senior High School
Connie Singleton	Robert Smalls Middle School
Donna South	Bay High School
Martin Wolfson	Lincoln Park Academy

YOUNG SCHOLARS

Mandy Dickerson	Hephzibah High School
Dan Fulcher	Hephzibah High School

RECENT MASTER'S DEGREE AND DOCTORAL RECIPIENTS

Edward Berg	Ph.D.	University of Georgia
Adrienne Edwards	M.S.	University of Georgia
Sheila Colwell	M.S.	University of Georgia
Dan Kaplan	Ph.D.	University of Georgia
Robert Lide	M.S.	University of Georgia
Charles Lydeard	Ph.D.	Auburn University
Kristina Schierenbeck	Ph.D.	Washington State University
Rebecca Yeomans	M.S.	University of Georgia

IV. PUBLICATIONS AND PRESENTATION

A. Journal Articles and Book Chapters Published

- 1642.¹ Scribner, K. T., M. C. Wooten, M. H. Smith, P. K. Kennedy, and O. E. Rhodes, Jr. 1992. Variation in life history and genetic traits of Hawaiian mosquitofish populations. *J. Evol. Biol.* 5:267-288.
- 1643.¹ Scott, D. E. and R. D. Dueser. 1992. Habitat use by insular populations of *Mus* and *Peromyscus*: What is the role of competition? *J. Anim. Ecol.* 61:329-338.
- 1644.¹ Dosskey, M. G. and D. C. Adriano. 1991. Trace metal impact on plants: Mediation by soil and mycorrhizae. Pages 105-115 in: E. S. Verry and S. J. Vermette (eds.). *The Deposition and Fate of Trace Metals in our Environment. Symposium Proceedings.* Philadelphia, PA. USDA Forest Service. Gen. Tech. Rep. NC-150.
- 1645.¹ Kramer, V. J., M. C. Newman, and G. R. Uitsch. 1992. Changes in concentrations of glycolysis and Krebs cycle metabolites in mosquitofish, *Gambusia holbrooki*, induced by mercuric chloride and starvation. *Environ. Biol. Fishes* 34:315-320.
- 1646.¹ Spotila, J. R. and M. P. O'Connor. 1992. Introduction to the Workshop: Biophysical Ecology: Methods, Microclimates, and Models. *Am. Zool.* 32:151-153.
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D. Presentations

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Aho, J. M. and M. E. Mulvey. Population biology of *Fascioloides magna* infections in white-tailed deer from South Carolina. American Society of Parasitologists Annual Meeting. Philadelphia, PA. August 1992.

Bryan, A. L., Jr. The SREL woodstork program: An overview of eight years of research. Savannah River Ecology Laboratory Seminar Program, University of Georgia. Aiken, SC. October 1992.

Bryan, A. L., Jr. Status of the Birdsville colony in 1992. Colonial Waterbird Society Annual Meeting. Oxford, MS. October 1992.

Bajt, S., S. B. Clark, S. R. Sutton, M. L. Rivers, D. B. Hunter, P. M. Bertsch, C. A. Langton, and J. V. Smith. Toxic metal oxidation states in low-level radioactive wasteforms: Initial chromium XANES results. National Meeting of the American Geophysical Union. San Francisco, CA. December 1992.

Bajt, S., S. R. Sutton, M. L. Rivers, J. V. Smith, and S. B. Clark. Synchrotron X-ray microprobe determination of chromate content using X-ray absorption near edge structure. The National Synchrotron Light Source Annual Meeting. Upton, NY. May 1993.

- Battaglia, L. L. and J. R. Keough. Early secondary succession in a Louisiana floodplain. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Bertsch, P. M., D. B. Hunter, and B. E. Herbert. *Invited Talk*. Probing inorganic and organic sorbate-sorbent environments by multi-NMR spectroscopy. American Chemical Society Annual Meeting. Denver, CO. March 1993.
- Bertsch, P. M. *Invited Talk*. Applications of X-ray microanalysis and microspectroscopy to problems in environmental science. Brookhaven National Laboratory Annual User's Meeting of the National Synchrotron Light Source. Upton, NY. May 1993.
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- Bildstein, K. L., I. L. Brisbin, Jr., and D. P. Ferral. Trophic upsurges and the responses of wading bird communities to changing conditions at three southern reservoirs, 1987-1993. Annual Meeting of the American Ornithologists' Union. Fairbanks, AK. June 1993.
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- Brisbin, I. L., Jr. Conserving threatened components of the world's faunal biodiversity: The untapped resources of children's zoo programs. South Regional Meeting of the American Association of Zoological Parks and Aquariums. Orlando, FL. March 1993.
- Brisbin, I. L., Jr. Radioactive contamination of wintering ring-necked ducks: Why ecotoxicologists need to understand basic waterfowl biology. Annual Meetings of the American Ornithologists' Union. Fairbanks, AK. June 1993.
- Bryan, A. L., Jr. and I. L. Brisbin, Jr. Post-drawdown utilization of the Par Pond Reservoir by foraging wood storks. Annual Meetings of the American Ornithologists' Union. Fairbanks, AK. June 1993.
- Bryce, A. L., W. A. Kornicker, A. W. Elzerman, and S. B. Clark. Metal desorption kinetics in a metal/ligand/sorbent system. Division of Environmental Chemistry, American Chemical Society Annual Meeting. Denver, CO. March 1993.
- Burke, V., N. Frazer, and J. W. Gibbons. Conservation of turtle: The Chelonian Dilemma. Annual Symposium on Sea Turtle Conservation and Geology. Jekyll Island, SC. February 1993.

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- Burke, V., J. W. Gibbons, and J. Greene. The extended nesting phenomenon of the common mud turtle *Kinosternon subrubrum*. Association of Southeastern Biologists Annual Meeting. Virginia Beach, VA. April 1993.
- Burrows, D. R. One year in the life of a QA Program for Research. Can a small organization survive? The American Society for Quality Control (ASQC) National Energy and Environmental Division Conference. Orlando, FL. September 1992.
- Burrows, D. R. *Invited Talk*. Savannah River Ecology Laboratory Quality Program. Westinghouse Savannah River Company, Reactor Quality Department. Aiken, SC. October 1992.
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- Caspersen, J., A. Schnabel, and R. R. Sharitz. Seed bank composition of a southeastern riverine swamp. Association of Southeastern Biologists Annual Meeting. Virginia Beach, VA. April 1993.
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- Chesser, R. K. *Invited Talk*. Evolution of mammalian social structure. Symposium on Mammalian Population Genetics. Lodz, Poland. August 1992.
- Chesser, R. K. Gene diversity and population organization: Paramount parameters, paradigms, paradox, and paralogisms of parapatri. Auburn University. Auburn, AL. February 1993.
- Ciravolo, T. G. and K. W. McLeod. Boron and plant growth: Bottomland tree seedlings. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Clark, S. B., N. M. Park, and R. C. Tuckfield. *Invited Talk*. Effects of sample collection device and filter pore size on concentrations of metals in groundwater samples. National Groundwater Sampling Symposium. Washington, DC. December 1992.
- Clark, S. B., N. M. Park, and R. C. Tuckfield. Methods for the collection of representative groundwater samples: Collection device and filtering effects on observed metals concentrations. National Meeting of the American Geophysical Union. San Francisco, CA. December 1992.

- Collins, B. S. and G. R. Wein. Oldfield community responses to frequency and intensity of clipping. Association of Southeastern Biologists Annual Meeting. Virginia Beach, VA. April 1993.
- Colwell, S. V., R. A. Kennamer, and I. L. Brisbin, Jr. Radiocesium concentrations in eggs and nesting wood ducks from a contaminated reservoir. Annual Meetings of the American Ornithologists' Union. Fairbanks, AK June 1993.
- Congdon, J. D. *Invited Seminar*. Delayed sexual maturity and longevity in Blanding's turtles: Implications for conservation of long-lived organisms. Annual Sea Turtle Meeting. Jekyll Island, SC. July 1992.
- Congdon, J. D. *Invited Talk*. Turtle Ecology and reproduction: Secrets of long-lived organisms revealed by 28 years of study. The Tinkle Lecture. University of Michigan. Ann Arbor, MI. October 1992.
- Congdon, J. D. Evolution of delayed sexual maturity and longevity. American Medical Association Conference on Senescence. Washington, DC. November 1992.
- Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. *Invited Talk*. Demographics of snapping turtles: Lessons for conservation and management of long-lived organisms. American Society of Zoologists Annual Meeting. Vancouver, B. C., Canada. December 1992.
- Congdon, J. D. *Invited Seminar*. Delayed sexual maturity and longevity in Blanding's turtles: Implications for conservation of long-lived organisms. Desert Tortoise Society Meeting. Las Vegas, NV. December 1992.
- Congdon, J. D. Conservation of long-lived organisms. Conference on Turtle Conservation and Management. Ann Arbor, MI. March 1993.
- Congdon, J. D. and R. E. Balinger. Reproductive investment by male yarrow's spiny lizards: A test of Darwin's hypothesis. American Society of Ichthyologists and Herpetologists and Herpetologists League Annual Meeting, *Sceloporous* Symposium. Austin, TX. May 1993.
- Cook, A. E. and J. Pinder III. *Invited Talk*. Relative accuracy of rectifications using coordinates determined from maps and global positioning systems. Annual ERDAS User's Group Meeting. Atlanta, GA. October 1992.
- Cook, A. E. GCPs: A comparison of ground control points derived from USGS 7.5 minute quad sheets and points obtained by hand-held GPS. Annual ERDAS Users Group Meeting. Atlanta, GA. October 1992.

- Cook, A. E. Image scanning calibration and set-up: Problems and solutions. Meeting of the South Carolina State Mapping Advisory Committee. Columbia, SC. October 1992.
- DeBiase, A. E. and B. E. Taylor. Local biogeography of diverse calanoid copepod assemblages. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
- DeBiase, A. E. and B. E. Taylor. Zooplankton assemblages in temporary ponds: The importance of chance. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Dixon, P. M. *Invited Talk*. Modeling water level changes in temporary wetlands. Biomathematics Program, North Carolina State University. Raleigh, NC. March 1993.
- Dixon, P. M. and P. Dang. Choosing among statistical models for sigmoidal curves. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
- Dixon, P. M. *Invited Talk*. Null models for neighborhood models of plant competition. Botany Department, University of Georgia. Athens, GA. September 1992.
- Dixon, P. M. Testing spatial segregation in multivariate point process. Auckland, New Zealand. November 1992.
- Dixon, P. M. Testing spatial segregation in multivariate point process. Melbourne, Australia. November 1992.
- Dixon, P. M. Reconstructing historical population dynamics in temporary ponds. Annual Southeast Mathematical and Statistical Ecology Conference. Highlands, NC. March 1993.
- Dosskey, M. G. and P. M. Bertsch. Contributions of organic C by wetland and upland forests to a blackwater stream. Soil Science Society of America Annual Meeting. Minneapolis, MN. October 1992.
- Dosskey, M. G. and P. M. Bertsch. Carbon transport through forest soils of the Atlantic Coastal Plain. North American Forest Soils Conference. Gainesville, FL. May 1993.
- Edwards, A. L. Population genetics of the rare *Asclepias texana* and its widespread sister species, *A. perennis*. Annual Meeting of the Society for the Study of Evolution. Snowbird, UT. June 1993.
- Everett, C. J., P. M. Bertsch, H. Tsai, and D. B. Hunter. Organic ^{32}P dynamics in forest soils as influenced by phosphorous fertilization. Soil Science Society of America Annual Meeting. Minneapolis, MN. November 1992.

- Fitzsimmons, N. Use of towed transmitter floats to investigate habitat use by sea turtles. Annual Meeting of the Society for the Study of Amphibians and Reptiles. El Paso, TX. August 1992.
- Gaiser, E. E. and B. Taylor. Holocene diatoms of a Carolina Bay wetland. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Garrett, K. A., P. M., Dixon, J. D. Gallant, B. E. Taylor, J. E. Pinder, III, and J. H. K. Pechmann. Predicting historical Carolina Bay hydroperiods from meteorological records using generalized additive models. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
- Gibbons, J. W. Research on reptiles and amphibians at SREL. Reptile Breeders Expo. Orlando, FL. August 1992.
- Gibbons, J. W. Using reptiles and amphibians in education programs. Palmetto Association of Independent Schools Conference. Columbia, SC. October 1992.
- Gibbons, J. W. *Invited Talk*. Reptiles and amphibians of the Savannah River Site. Sierra Festival. Lake Marion, SC. October 1992.
- Gibbons, J. W. Long-term studies with long-lived turtles: Life in the slow lane. Gopher Tortoise Council. Fargo, GA. October 1992.
- Gibbons, J. W. *Invited Talk*. Studies of turtles on Kiawah Island. Kiawah Island Community Association. Kiawah Island, SC. October 1992.
- Gibbons, J. W. *Invited Talk*. Long-term studies with long-lived turtles: Life in the slow lane. Valdosta State College. Valdosta, GA. November 1992.
- Gibbons, J. W. *Invited Seminar*. Long-term research and long-lived reptiles: Life in the slow lane. Coastal Carolina Herpetocultural Society. Charleston, SC. January 1993.
- Gibbons, J. W. *Invited Talk*. Who's watching the snakes, and why: Research on reptiles and amphibians of the Savannah River Site. Sierra Club. Florence, SC. April 1993.
- Gibbons, J. W. *Invited Talk*. How to catch alligators for research in one easy lesson and three hard ones. Southwestern Association of Naturalists Annual Meeting. Springfield, MO. April 1993.

- Heagler, M. G., M. C. Newman, M. E. Mulvey, and A. Chazal. Mesocosm populations of mosquitofish chronically exposed to inorganic mercury: Fecundity-genotype correlations. Annual Meeting of the Society of Environmental Toxicology and Chemistry. Cincinnati, OH. November 1992.
- Herbert, B. E. Characterization of dissolved and colloidal organic matter in soil solution: A critical review. North American Forest Soils Conference. Gainesville, FL. May 1993.
- Hinton, T. G. Contaminated soil on Chernobyl vegetation. Environmental Health Physics Meetings. January 1993.
- Hunter, D. B. and P. M. Bertsch. *Invited Talk*. Clay surface-facilitated degradation reactions and mechanisms of tetraphenylboron studied noninvasively by IR. V. M. Goldschmidt Conference. Reston, VA. May 1992.
- Hunter, D. B. *Invited Seminar*. The Application of physics in the developing field of environmental science. The Association of Physics Students, Presbyterian College. Clinton, SC. November 1992.
- Imm, D. W. and J. S. Clark. Relationships between distributional patterns and climate sensitivities of common eastern North American tree species. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
- Imm, D. W. and K. B. McLeod. Patterns of composition and diversity in an upper coastal plain forest. Association of Southeastern Biologists Annual Meeting. Virginia Beach, VA. April 1993.
- Jagoe, C. H. Toxicity and gill damage in freshwater fish due to beryllium in soft, acidic water: Analogies between Be and Al toxicology and chemistry. Annual Meeting of the Society of Environmental Toxicology and Chemistry. Cincinnati, OH. November 1992.
- Jagoe, C. H., A. Favre, and M. C. Newman. Effects of mercury (II) on the gills of fish: Ultrastructure and histochemical localization. Annual Meeting of the Society of Environmental Toxicology and Chemistry. Cincinnati, OH. November 1992.
- Jagoe, C. H., R. K. Chesser, M. H. Smith, I. L. Brisbin, Jr., C. E. Dallas, and S. K. Fischer. Effects of the Chernobyl nuclear accident on freshwater organisms and ecosystems in Ukraine. Annual Meeting of the American Association for the Advancement of Science. Boston, MA. February 1993.
- Jenssen, T. A. Annual reproductive cycle of the Jamaican lizard, *Anolis opalinus*. The Society for the Study of Amphibians and Reptiles Annual Meeting. El Paso, TX. August 1992.

- Kaplan, D. I., P. M. Bertsch, and D. C. Adriano. Role of natural organic materials and pore water flow velocity on subsurface mobile colloid generation. Soil Science Society of America Annual Meeting. Minneapolis, MN. October 1992.
- Kaplan, D. I. and P. M. Bertsch. Mobile colloids and the transport of metals through an acidified aquifer. American Geophysical Union Spring Meeting. Baltimore, MD. April 1993.
- Kaplan, D. I., D. C. Adriano, and P. M. Bertsch. Mobile colloids and the transport of metals through an acidified aquifer. National Meeting of the American Geophysical Union. Baltimore, MD. May 1993.
- Keeland, B. D. and R. R. Sharitz. A comparison of wetland tree growth in Louisiana and South Carolina. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
- Keeland, B. D. and R. R. Sharitz. The effects of hydrologic regime on wetland tree growth. International Wetland Conference. Columbus, OH. September 1992.
- Keeland, B. D. and R. R. Sharitz. The effects of water level fluctuation on weekly tree growth in a southeastern swamp: An application of transfer function modelling. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Kenamer, R. A. Body mass dynamics of incubating wood ducks. Annual Meetings of the American Ornithologists' Union. Fairbanks, AK. June 1993.
- Kroh, G. C. and J. E. Pinder III. Remote sensing studies in Lassen Volcanic National Park: An example of GIS applications in National Parks. Redwoods National Park Headquarters. Arcata, CA. July 1992.
- Leff, L. G., J. V. McArthur, J. L. Meyer, and L. J. Shimkets. Exchange of bacteria among stream habitats: The role of invertebrates and flow rate. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
- Leff, L. G. *Invited Talk*. Ecology of bacteria in a coastal plain stream: Experimental and molecular approaches. Miami University. Department of Microbiology. Oxford, OH. March 1993.
- Leff, L. G. *Invited Talk*. Molecular approaches to ecology of stream bacteria. Pennsylvania State University, Erie, PA. March 1993.
- Leff, L. G. *Invited Talk*. Ecology of bacteria in a coastal plain stream: Experimental and molecular approaches. Villanova University, Department of Biology. Villanova, PA. April 1993.

- Leff, L. G. *Invited Talk*. Ecology of bacteria in a coastal plain stream: Experimental and molecular approaches. University of Dayton, Department of Biology. Dayton, OH. April 1993.
- Leff, L. G., J V. McArthur, J. L. Meyer, and L. J. Shimkets. The role of different stream habitats as sources or sinks for bacterial populations. North American Benthological Society Annual Meeting. Calgary Alberta. May 1993.
- Leff, L. G., M. F. Plagwitz, J V. McArthur, and L. J. Shimkets. Comparisons of efficiency and yield among methods of DNA extraction from stream sediments. American Society of Microbiology Annual Meeting. Atlanta, GA. May 1993.
- Leff, L. G., J V. McArthur, and L. J. Shimkets. Use of environmental DNA to describe stream sediment bacterial assemblages. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Lewis, P. J., J. P. Megonigal, and R. R. Sharitz. False-ring formation of baldcypress sapling in two flooding regimes. International Wetlands Conference. Columbus, OH. September 1992.
- Lewis, P. J., B. D. Keeland, and R. R. Sharitz. Growth response of baldcypress from altered hydrologic regimes. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Lydeard, C. M. *Invited Talk*. Historical biogeography of the Caribbean basin as inferred from mitochondrial DNA sequences of the fish genus *Gambusia*. University of Central Florida. Orlando, FL. November 1992.
- Lynch, T. K. Ecology of ground skinks (*Scincella lateralis*) in South Carolina. Association of Southeastern Biologists Annual Meeting. Virginia Beach, VA. April 1993
- Martin, H. W. Minimizing hazardous waste and regulated pollutants generated by soil research. Environmental Soil Science Conference. Edmonton, Alberta, Canada. August 1992.
- Martin, H. W. and D. L. Myhre. Phosphogypsum effects on soil chemistry in spodosols planted to citrus. Soil Science Society of Annual Meeting. Minneapolis, MN. October 1992.
- Martin, H. W., D. C. Adriano, G. Sick, and D. Gibson. Cultivation of beauty berry, *Callicarpa americana*, a shrub native to the southeast U.S. Monthly Meeting of Aiken, Richmond, and Columbia County Professional Nursery Growers' Association. Augusta, GA. November 1992.

- Martin, H. W. *Invited Talk*. Observations and hypothesis testing in soil fertility and chemistry. Agronomy and Soils Department. Auburn University. Auburn, AL. January 1993.
- Martin, H. W. *Invited Talk*. Land application of solid waste: Fly ash and phosphogypsum. Cook College. Rutgers University. New Brunswick, NJ. March 1993.
- Martin, H. W. and W. G. Harris. *Invited Talk*. Mineralogy of clay sediments in phreatic caves of the Suwannee River basin. National Speleological Society Cave Diving Section, Spring Workshop. Brandford, FL. June 1993.
- McAlpine, S., C. McCreedy, I.L. Brisbin, Jr., and O. E. Rhodes, Jr. Population structure of Wintering American coots. Annual Meetings of the American Ornithologists' Union Fairbanks, AK. June 1993.
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- McArthur, J V. *Invited Talk*. Spatial and temporal dynamics of microbial populations. Department of Biology. Auburn University. Auburn, AL. March 1993.
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- Mills, G. L. Lipid composition of forest soil profiles across an upland - floodplain toposequence. North American Forest Soils Conference. Gainesville, FL. May 1993.
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- Rhodes, O. E. Jr. Apportionment of genetic variance in migrating and wintering mallards. Annual Meetings of the American Ornithologists' Union. Fairbanks, AK. June 1993.
- Schierenbeck, K. A., R. N. Mack, and R. R. Sharitz. Differential effects of herbivory on relative growth rates and root: shoot allocation between native and introduced species of *Lonicera*. Ecological Society of America Annual Meeting. Honolulu, HI. August 1992.
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- Sharitz, R. R. *Invited Talk*. Wetland ecosystems. USDA Forest Service Symposium, Ecosystem Principles and Concepts. Northeastern Forest Experiment Station. Philadelphia, PA. October 1992.
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- Sharitz, R. R. *Invited Talk*. Southeastern swamps and the challenges that face them. Atlanta Botanical Garden. Atlanta, GA. February 1993.
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- Shimkets, L. J. *Invited Talk*. Molecular microbial ecology: Streams and genes. Department of Microbiology, University of Alberta. Edmonton, Alberta, Canada. May 1993.
- Shimkets, L. J., L. G. Leff, J. R. Dana, and J. V. McArthur. Factors influencing spatial differences in the composition of bacterial assemblages in a stream. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Smith, M. H. Morphological asymmetry in mammals: genetics and homeostasis reconsidered. Symposium on Mammalian Population Genetics. University of Lodz, Poland. August 1992.
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- Weeks, S. C. Sex and the benefits of genotypic diversity in a heterogeneous environment; Performances of clonal and sexual fish *Poeciliopsis* in monoculture and in mixtures. American Genetic Association Symposium on the Evolution of Sex. Blacksburg, VA. July 1992.
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- Winkleman, D. L. *Invited Talk*. Genetic differences in growth between dollar sunfish populations. The American Fisheries Society National Meeting. Boise, ID. September 1992.
- Wise, M. G., J. V. McArthur, and L. J. Shimkets. The use of DNA hybridization to assess spatial diversity of bacterial plasmids in a blackwater stream. American Society of Limnology and Oceanography and Society of Wetland Scientists Annual Meeting. Edmonton, Alberta, Canada. June 1993.
- Yeomans, S. R. Turtle orientation: Field tests of water-finding ability in adult aquatic turtles. Association of Southeastern Biologists Annual Meeting. Virginia Beach, VA. April 1993.

Figure 1. Organizational Chart, Savannah River Ecology Laboratory

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