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SAVANNAH RIVER ECOLOGY LABORATORY

ANNUAL TECHNICAL PROGRESS REPORT

OF

ECOLOGICAL RESEARCH

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AND THE U.S. DEPARTMENT OF ENERGY

FOR THE YEAR ENDING

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Michael H. Smith, Director

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SUMMARY

The Savannah River Ecology Laboratory (SREL) is a research unit of the University of Georgia (UGA). The overall mission of the Laboratory is to acquire and communicate knowledge of ecological processes and principles. SREL conducts basic and applied ecological research, as well as education and outreach programs, under a contract with the U.S. Department of Energy (DOE) at the Savannah River Site near Aiken, South Carolina. Significant accomplishments were made during the past year in the areas of research, education and service.

Major additions to SREL facilities were completed that will enhance the Laboratory's work in the future. Following several years of planning, opening ceremonies were held for the 5,000 ft^2 multi-purpose conference center that was funded by the University of Georgia Research Foundation (UGARF). The center is located on 68 acres of land that was provided by the U.S. Department of Energy. This joint effort between DOE and UGARF supports DOE's new initiative to develop partnerships with the private sector and universities. The facility is being used for scientific meetings and environmental education programs for students, teachers and the general public. A 6,000 ft^2 office and library addition to SREL's main building officially opened this year, and construction plans are underway on a new animal care facility, laboratory addition, and receiving building.

The Laboratory's research mission was fulfilled with the publication of two books and 98 journal articles and book chapters by faculty, technical staff, students, and visiting scientists. An additional five books and about 91 journal articles currently are in press. Faculty, technicians and students presented 193 lectures, scientific presentations, and posters to colleges and universities, including minority institutions. Several other noteworthy events took place as several faculty members were invited to teach in Europe this past year. Last Fall, Dr. Domy Adriano taught a graduate course at the Institute of Soil Science, University of Agriculture and Forest Resources in Vienna, Austria. In April, Dr. Rebecca Sharitz taught a graduate course in Sweden, which was sponsored by the Swedish government and Umeå University. Also in April, Dr. Michael Newman was invited by the Society for Environmental Toxicology and Chemistry to teach a short course at their annual meeting in Surrey, England.

The research divisions at SREL continue to progress. Scientists from the Division of Wildlife Ecology and Toxicology traveled to the Chernobyl nuclear site in Ukraine twice this past year to continue their research on the genetic effects of radiation on animal populations. Geographic Information System technologies, used in the Division of Wetlands Ecology, have enabled scientists to make significant discoveries about the forest areas in the coastal regions of Georgia. Almost two million dollars was obtained by a scientist in the Division of Biogeochemical Ecology for the establishment of an Advanced Analytical Center for Environmental Sciences. This center will include a modern laboratory and user facility for the innovative application of advanced instrumentation to address environmental concerns.

Several faculty members were awarded for their scientific achievements. Dr. Paul Bertsch was promoted to senior research scientist and full professor of Agronomy with tenure by The University of Georgia. A distinguished alumni award was given to Dr. Justin Congdon by the California Junior College System and Dr. J. Whitfield Gibbons was honored with a prestigious teaching award by the Association of Southeastern Biologists. Dr. Michael Smith was recognized as a fellow of the American Association for the Advancement of Science, and Dr. F. Ward Whicker

was presented with the 1994 Distinguished Alumni Service Award by the Health Physics Society. Finally, Dr. Sue Clark was appointed to a National Academy of Sciences committee on the Waste Isolation Pilot Plant.

Participants in SREL's education program during 1994 and 1995 came from schools located throughout the United States and included 40 undergraduate students, 53 graduate students, 10 pre-college teachers, 3 visiting faculty and 4 high school students. These participants come from nearly half of the states, emphasizing the national stature of the SREL program.

In addition to holding faculty positions at The University of Georgia, various SREL faculty have adjunct status at sixteen other colleges and universities. Faculty, staff and students also are active in providing outreach and service to the scientific community. Representatives from SREL hold more than 40 editorial or committee positions in national groups and organizations. SREL representatives also serve on several UGA academic and administrative committees.

SREL's Division of Outreach and Education reaches a different audience in its successful efforts to communicate scientific awareness to the general public. In 1994, Outreach staff gave more than 300 presentations to schools, civic groups and similar audiences. This year, the Division received an Award of Excellence in the category of Institutional Relations Projects from the Council for the Advancement and Support of Education in the Central Savannah River Area.

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

Several steps were taken to improve the overall management and operation of SREL. A new Laboratory-wide electronic communication program was installed and is in use. The management team was restructured to include representatives from support staff and technicians. An outside peer review of research programs was conducted for the Division of Wetlands Ecology. Internal performance reviews were completed for both the head of the Division of Wetlands Ecology and the head of the Division of Biogeochemical Ecology, and the new UGA evaluation system was initiated for all classified employees. Also, an initial internal evaluation of current research programs was completed to assess their relevance to the changing mission of the Department of Energy/Savannah River Site.

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 ECOSYSTEM RESTORATION AND REMEDIATION

Environmental History of Carolina Bays

B.E. Taylor and M.J. Brooks (SR-ARP)

The environmental history of Carolina bays research project is a collaboration between SREL and the Savannah River Archive Program which provides information and contributes to our understanding of the development and stability of Carolina bay aquatic communities. This research is important for determining appropriate goals for the restoration and remediation of Carolina bay communities that have been impacted by human activities.

Six set-aside Carolina bays were selected for studies of their environmental histories during both the prehistoric and modern eras: Flamingo Bay (#3 in the original SRS Carolina bay inventory), Mona Bay (#66), Woodward Bay (#67), Craig's Pond (#77), Sarracenia Bay (#78), and Thunder Bay (#83). Criteria included availability of modern ecological baseline data and archaeological potential. An additional site, Restoration Bay (#93), has been included in historic era studies.

Archaeological surveys on the rims of the bays have revealed a long history of human occupation. Flamingo Bay was used most heavily, and diagnostic artifacts have been recovered from every major prehistoric cultural period since the Early Archaic (beginning about 10,000 yr B.P.). From the chronology of basin infilling and from a decrease in the intensity of human activity, we speculate that this pond may have begun to assume its modern seasonal character during the late Holocene, after 4000 yr B.P.

E. E. Gaiser, a doctoral student at the University of Georgia, is using siliceous microfossils from the sediments of the ponds to reconstruct environmental histories. During the past year, she prepared a reference set of phytoliths (siliceous material accumulated in epidermal cells) from 283 species of vascular plants. She completed identification of more than a hundred species diatoms from a survey of modern ponds and then used multivariate techniques to determine relationships between assemblage composition of diatoms and microhabitat and environmental variables. Several diatom species are reliable indicators of pond drying. She has begun to extract and identify microfossils from soil cores from FlamingoBay. Diatoms are preserved in strata dating back to the mid-Holocene; sponge spicules and phytoliths are preserved in deeper strata. We hope that these data will illuminate possible causes of the mid-Holocene shift in human activity at Flamingo Bay.

Historic record searches for the ponds began with records of land acquisition by the Atomic Energy Commission in 1951. For most of the ponds, ownership and other records were traced back to the nineteenth century. Agricultural censuses show that rice and sugarcane were produced on some of these tracts in the late 1800s. We have yet not established whether this production occurred in the ponds, and we are investigating potential sources of corroborative data. Evidence concerning clearing of vegetation in or around the ponds or ditching or draining of the ponds is particularly important for interpreting current vegetation and recent successional processes in these habitats.

Recovery of a Cypress-tupelo Forest Following Thermal Disturbance

Rebecca R. Sharitz, Catherine J. King and Diane De Steven

During the 40-year period of SRS nuclear reactor operations, cooling-system waters were

discharged into several tributary streams flowing into the floodplain of the Savannah River, destroying large areas of the original swamp forest. Since reactor shutdown, demonstration plots to evaluate techniques for wetland restoration have been established by SREL scientists in Fourmile Branch and large-scale efforts to restore the forest vegetation have been undertaken by the U.S. Forest Service in Pen Branch. The cost-effectiveness of these restoration efforts must be evaluated by comparison with natural recovery of the wetland forest vegetation. Two projects, one in Fourmile Branch delta and the other in the lower portion of the Pen Branch delta, have been conducted to assess the pattern and rate of natural forest recovery and to serve as a framework for evaluating the effectiveness of wetland restoration programs.

In 1987, permanent plots were established in the corridor and delta of Fourmile Branch to measure the rate and pattern of plant succession following cessation of C-Reactor activities in 1985. The vegetation in these plots was sampled in 1987, 1989 and 1993. These data are being combined with remotely sensed imagery to assess the invasion of woody plant species. Aerial photographs taken in 1985, 1990 and 1993 have been rectified and classified using Geographic Information System (GIS) Technology. Data from the field samples are being summarized to determine major types of woody plant associations and to assess the accuracy of the classifications. The classified images are being analyzed using change detection techniques to determine the location and quantity of woody plant invasion. The major tree species that are becoming established in the Fourmile delta are loblolly pine (*Pinus taeda*) and willow (*Salix* spp.), both early successional species that are wind-dispersed. There has been very limited recruitment of the original hardwood and swamp forest canopy species.

In contrast, in portions of the Pen Branch delta, recovery five years after the shutdown of K-Reactor in 1988 has included the canopy species water tupelo (*Nyssa aquatica*) and baldcypress (*Taxodium distichum*). The degree of recovery and composition is related to the availabliity of seeds and suitable conditions for germination and seedling establishment. In the most disturbed portions of the delta where no canopy trees remained, the dominant vegetation is persistent emergent marsh, with cattails (*Typha* spp.), bulrush (*Scirpus cyperinus*), water primrose (*Ludwigia* spp.) and marsh St. John's-wort (*Hypericum walteri*) the most abundant species. Where at least a few canopy trees survived, however, there are high densities of water tupelo and baldcypress saplings, as well as willows (*Salix* spp.) and several species of shrubs. The similarity in size-class distributions of the woody saplings suggests relatively synchronous recruitment, and basal tree-ring counts of selected saplings show that establishment occurred in 1985-1986, prior to reactor shutdown. Water level data collected from a recorder on the Pen Branch delta show that floods occurred during the growing season of 1984 and again in the early 1990s, but not during 1985-1989. Thus, the survival of a few trees that produced seeds and the absence of growing season floods provided a window of opportunity for natural regeneration of canopy species to occur. Once established, these saplings attained a size that enabled them to survive subsequent growing season floods following reactor shutdown.

Carolina Bay Restoration

R.R. Sharitz and G.R. Wein

There are more than 200 Carolina bay wetlands on the SRS. Many of these have ditches that originally functioned to drain water from or into these natural depressions. Although these ditches

were dug prior to 1951, some of them still function to drain water from the wetlands. As a result, wetland vegetation is replaced by upland plant species and other natural functions of these wetland systems are lost.

SREL and SRFS, in cooperation with NUS, have developed a research program to evaluate efficient methods for restoring Carolina bay wetlands and management practices that may enhance restoration. The first aspect that needs to be considered in wetland restoration is returning the hydrologic condition to one that will support wetland biota and functions. A four-hectare Carolina bay (Bay 93) supported herbaceous marsh vegetation in 1951, according to surveys of aerial photography. Drainage of the bay since that time has permitted the invasion of upland species, including loblolly pine and sweetgum. In November 1993, the ditch in Bay 93 was plugged, approximately 50% of the timber was removed, and a portion of the remaining forest and clearcut was burned to remove existing litter.

Julian Singer, M.S. student in the Botany Department, University of Georgia, examined vegetation in Bay 93 prior to application of these restoration treatments and for two years following blockage of the drainage ditch. In the first year, the bay was only shallowly filled with water, and the vegetation remained dominated by upland species. During the second year, the water was more typical of undrained bays, and the vegetation was characterized by more wetland herbaceous species. The increased light and soil disturbance created by the removal of the forest vegetation and the burning stimulated germination of herbaceous species from the seed bank and accelerated recovery of the herbaceous marsh in these treatments.

This research is being incorporated into the SREL program on Ecosystem Restoration and Remediation. Restoration of previously disturbed Carolina bay wetlands may be a reasonable means of mitigating the loss of other wetlands on the SRS. Results of this research could save considerable funds by determining the ecologically best and most efficient methods for wetland restoration.

Carolina Bay Hydrology and Vegetation

B. Collins

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

The interaction of Carolina bay hydrology with the vegetation and the seed/propagule bank currently is being investigated. The general objective is to determine how hydrology influences clonal spread of perennial plants and germination from the seed bank. Six set-aside herbaceous bays are being studied: Mona Bay, Woodward Bay, Craig's Pond, Sarracenia Bay, Dry Bay, and Ellenton Bay.

To date, soil cores have been removed from each bay from points within the bay that have a 90 %, 75 %, 50 %, or 25 % chance of being flooded in any given year. Cores have been placed in flooded or unflooded conditions, and the vegetation arising from each will be censused to determine 1) if the distribution of seeds and propagules reflects hydrology; 2) if the vegetation reflects the seed/propagule bank; and 3) if the contribution of the seed/propagule bank varies with hydrology.

Recent Publications: Ecosystem restoration

Brooks, M.J., B.E. Taylor, and D.J. Colquhoun. 1994. Holocene climate and upland landscape evolution in the Upper Coastal Plain of South Carolina. *In* Annual Review of Cultural Resource Investigations by the Savannah River Archaeological Research Program, Fiscal Year 1994, pp. 29-33. South Carolina Institute of Archaeology and Anthropology, University of South Carolina, Columbia, South Carolina.

Taylor, B.E., and M.J. Brooks. 1994. Modern climate and water level predictability in a Carolina bay on the SRS: a baseline for interpreting the geoarchaeological record. *In* Annual Review of Cultural Resource Investigations by the Savannah River Archaeological Research Program, Fiscal Year 1994, pp. 33-40. South Carolina Institute of Archaeology and Anthropology, University of South Carolina, Columbia, South Carolina.

A.2 SRS STREAMS

Aqatic Invertebrate Biodiversity of Upper Three Runs Creek and Contaminated Streams

J V. McArthur

Cheumatopsyche richardsoni, a caddisfly, is unique in that it is endemic to Upper Three Runs Creek yet it is one of four congeners occurring in the stream. The other species are *C. pasella, C. pinaca* and *C. pettiti*. This combination of factors makes *C. richardsoni* an ideal species to study endemism's effect on genetic diversity. We hypothesized that *C. richardsoni*'s genetic variability would be lower than that of its congeners due to the nonexistence of gene flow from outside populations. However, over nine times as many *C. richardsoni* adults were collected than of it congeneric species. This led to an alternate hypothesis that *C. richardsoni* may harbor more genetic variability that its congeners due to a relatively large population size. The four *Cheumatopsyche* species were analyzed for isozyme variation using cellulose acetate electrophoresis. A total of 29 enzymes were screened. Of these, 18 enzymes representing 24 presumptive loci were reliably scored for all individuals. Data analysis indicates that morphological differentiation separates these species, one new species, *C. edista* also has been found. *C. richardsoni* had more fixed alleles than the other species indicating lower genetic diversity. These data are important to SRS operations with regard to decisions concerning Upper Three Runs Creek. While only this small group of aquatic insects has been examined at this level, we know that there are over 650 species of invertebrates in this creek, making it one of the most species rich streams in the world. Included among these species are others that are endemic to Upper Three Runs Creek or have limited distributions. Our data suggest the precarious state of some of these organisms.

Recent Publications: SRS Streams

Aho, J.M., J V. McArthur, R.B. Rader, and R.W. Wolfe. 1995. Leaf litter processing in a southeastern blackwater stream: roles of season and leaf quality. Archiv fur Hydrobiologie (in press).

Rader, R.B., J V. McArthur and J. M. Aho. 1994. Relative importance of mechanisms determining decomposition in a southeastern blackwater stream. The American Midland Naturalist 132:19-31.

Rader, R.B. and J V. McArthur. 1995. The relative importance of refugia in determining the drift and habitat selection of predaceous stoneflies in a sandy-bottomed stream. Oecologia 103:1-9.

Wagele, J.W., N.J. Voelz and J V. McArthur. 1995. Older than the Atlantic Ocean discovery of a feshwater Microcerberus (Isopoda) in North America and erection of Coxicerberus n. gen. The Journal of Crustacean Biology (in press).

A.3 TRACE ORGANIC COMPOUNDS

Environmental Organic Chemistry

G.L. Mills and R.J. Hudson

In the broadest context, this research investigates the processes that affect the mobility and fate of contaminant organic compounds in both surface and subsurface environments. These processes include abiotic reactions such as sorption, photochemical, hydrolysis, oxidation, and reduction, as well as biological transformations. The change in concentration with time of a contaminant in a designated compartment of a ecosystem and the rate of movement between compartments is determined by the sum of these processes. Generally, one or two of these reactions will predominate, depending upon the geochemical matrix and environmental conditions. This research program seeks to identify the important reaction pathways, quantify the reaction rates, and determine the environmental variables that control these rates. Recent studies in this program have focused on two major types of reactions: sensitized photochemical reactions and sorption reactions.

Photochemical Reactions: Photochemical reactions are an important pathway for the transformation of many organic compounds in natural waters and on the surfaces of soils and sediments irradiated with light. These reactions are categorized into direct and indirect photolysis. Direct photolysis refers to reactions in which the compound absorbs light and consequently undergoes a chemical change. Indirect, or sensitized, photochemical reactions are initiated when light is absorbed by organic matter other than the organic substrate of interest and is elevated to an electronically excited energy state. The excited compound can react directly with the substrate or produce reactive transient molecules that can subsequently react with the substrate. Many studies have shown that naturally occurring dissolved organic matter (DOM) can act as an effective sensitizer in the indirect photolysis of many organic compounds in aquatic systems. These reactions are particularly important in the blackwater stream systems on the Southeastern Coastal Plain which are characterized by their low ionic strength and relatively high concentration of DOM and thus differ from clearwater systems which are dominated by inorganic solutes.

Studies in this program are determining the ability of DOM in the aquatic systems on the SRS to sensitize the photochemical transformation of organic compounds that are of interest to the DOE. Sunlight irradiation of dissolved organic matter (DOM), as well as its specific humic and fulvic acid components, has been shown to initiate the photoproduction of a variety of reactive products which can subsequently transform organic pollutants. These DOM-derived reactive intermediates include singlet oxygen, O_2, the superoxide anion, $O_2^{\cdot}$, organoperoxy radicals, $RO_2^{\cdot}$, and humic molecules in a excited energy state.

In general, the reaction rates can be described by apparent first-order kinetic models when the pollutant concentration is low and has a negligible effect on the lifetime of the reactive transient species, and the sensitizer concentration does not change significantly during the irradiation period. Under these conditions, the concentration of reactive transient is maintained at a steady state concentration. Information regarding photodegradation pathways can be obtained by adding compounds which selectively react with transient oxidants and consequently decrease their solution concentration. This results in a change in the overall rate of photodegradation of the pollutant compound. By selectively targeting different transient oxidants in a series of experiments, the

influence of each oxidant on the overall degradation rate of the pollutant can be evaluated. In this manner the reaction pathway is identified and the persistence (i.e., half-life) of the contaminant can be estimated using environmental photochemical models.

Sorption Reactions: The second component of this research program examines the effects of organic matter in soils and sediments on sorption reactions of contaminant organic compounds. In carbon rich environments, partitioning to natural organic materials is known to be the primary mechanism controlling the removal of hydrophobic organic compounds (HOC) from the aqueous phase in surface and subsurface environments. The sorptive behavior of HOC in environments containing low organic carbon concentrations (<0.02%), such as subsoils and aquifer sediments, is poorly understood. Fewer studies have examined these systems and the studies that have been done have demonstrated that sorption behavior is more complex and can include both partitioning into organic matter and adsorption onto clay mineral or oxide surfaces. The system is further complicated by the presence of mobile colloids comprised of both organic and inorganic components. Since much of the subsurface environment on the SRS contains low carbon substrates, a better understanding of the reactions controlling HOC solute behavior in these systems is critical to generating accurate transport and risk assessment models.

Studies conducted in this component of the research program are designed to elucidate the predominate reactions controlling contaminant organic solute behavior in soils and unconsolidated geological substrates characterized by low organic matter content. Previous studies have suggested that the qualitative characteristics of the organic matter in these systems may be different from those in surface soils and sediments and that these differences may influence the sorptive properties of these materials.

^{14}C-labeled organic compounds are commonly used as solute tracers in sorption reaction studies involving column transport and batch reaction experiments; however, there are disadvantages to using this type of tracer. One disadvantage is that the ^{14}C-isotope is radioactive, requiring special precautions with its use and disposal. Another disadvantage is that multiple solutes cannot be used simultaneously when detected by liquid scintillation radioassay methods. Non-labeled (^{12}C) compounds can be used simultaneously, but they cannot be used if they are present as a background component of the sample matrix being investigated, which is a possibility in systems containing a chemically complex petroleum hydrocarbon phase.

An alternative to ^{14}C labeled tracers are compounds labeled with the hydrogen isotope deuterium (i.e., deuterated). Because the hydrogen atoms have been replaced by deuterium atoms, the mass of a deuterated organic compound is increased while keeping the structure and chemical properties of a non-labeled organic compound. Deuterated compounds are commonly added to samples as internal standards to quantify sample components during analysis. Recently, they have also been used as tracers to identify biosynthetic pathways in plants and beetles. However, the use of deuterated compounds as tracers in column transport or batch reaction studies has not been previously reported.

Studies recently have been completed to evaluate the use of deuterated organic compounds as tracers in sorption reaction studies involving sorbing substrates contaminated with petroleum hydrocarbons. Deuterium-labeled organic compounds were evaluated as an alternative to ^{14}C-labeled or non-labeled (^{12}C) compounds in sorption reactions studies involving petroleum hydrocarbons. To demonstrate their utility as tracers in the presence of petroleum hydrocarbons, samples of crude oil

and weathered diesel oil were spiked with deuterated acenapthene, fluorene, and dibenzothiophene, and then analyzed by gas chromatography-mass spectrometry (GC-MS). Data collected in selective ion monitoring mode (SIM) versus total ion mode showed that specific compounds could be easily identified in complex mixtures, and that tracers could be detected simultaneously. This technique has been used to examine the sorptive effects of weathered residual diesel fuel on the transport of polycyclic aromatic hydrocarbons (PAH) in low-carbon aquifer sediments obtained from the SRS. Current studies are examining the relationship between qualitative characteristics of the natural carbon in the aquifer matix and the sorptive behavior of the PAH solutes.

Recent Publications: Environmental Organic Chemistry

Hudson, R.J., G.L. Mills, and B.E. Herbert. Deuterium-labelled organic compounds as solute tracers in sorption reactions involving petroleum hydrocarbons. J. Environmental Quality (in press).

Hudson, R.J., G.L. Mills, and B.E. Herbert. Sorption of hydrophobic organic compounds to residual diesel oil in aquifer materials. Environmental Science and Technology (in press).

Mills, G.L. and Sullivan L.R. Indirect photolysis of tetraphenylborate sensitized by humic acid. Chemosphere (in press).

A.4 RADIOECOLOGY

Distribution and Dynamics of Radionuclides in Aquatic Ecosystems

F.W. Whicker and T.G. Hinton

This research is concerned with the general need to measure the concentrations of radionuclides in components of contaminated ecosystems on the SRS, and to understand the basic processes that control the long-term dynamics of these contaminants. The research provides site-specific data for DOE and WSRC upon which sound risk analyses for various management alternatives can be conducted.

The drawdown of Par Pond reservoir exposed 5 km^2 of sediments containing low levels of radionuclides, primarily ^{137}Cs. The Environmental Protection Agency perceived that contamination levels were sufficient to declare Par Pond a CERCLA site. Radioecological studies on the exposed Par Pond sediments were initiated in July 1991 and continued through refill, which began in August 1994 and was completed on 15 March 1995. The studies still are ongoing.

Primary results from 1991-1994:

- Dose calculations indicate that a person subsisting on the unremediated, exposed sediments for 30 years could receive an effective dose equivalent of over 140 mSv from external, ingestion and inhalation pathways. This leads to a lifetime health risk of 10^{-2}, suggesting that remediation efforts may be required if subsistence farming is the long-term land use chosen for Par Pond.

- Garden vegetables were grown on the exposed lake bed and ^{137}Cs concentrations in plants were 1 to 6 times greater than the concentrations in the sediments. Such high concentration ratios are considerably larger than those used in generic risk analysis computations, and highlight the need for site specific data.

- Concentrations of ^{137}Cs in bass have doubled since the drawdown. The increase is significantly correlated ($p < 0.01$) to a decline in stable potassium concentrations in the water ($R = -0.70$), and to a general decline in fish health as indicated by a condition factor ($p = 0.04$, $R = -0.53$). We suspect this is because the nutrient rich Savannah River water is not longer pumped into the reservoir.

- Sediment cores reveal that essentially all the ^{137}Cs is in the top 30 cm, with a peak concentration occurring between 4 and 8 cm.

- Ecological risk calculations were performed for fish inhabiting the Par Pond system over the last 30 years using a screening-type modeling approach. Conservative dose estimates to the fish were 0.2 mGy d^{-1}. The probability of impaired reproduction or fish mortality occurring at this low dose rate is extremely low, as mortality has never been documented at levels below 10 mGy d^{-1}. The probabilities are especially low because we are confident that the actual

doses received by fish were less than our intentionally conservative calculations.

- The Par Pond Radioecology Laboratory had its grand opening in October 1993. The new facility substantially increased our research capabilities.

Primary activities in 1995:

- The last annual surveys of terrestrial vegetation and external gamma exposures on the exposed lake bed prior to refill were conducted. Surveys of aquatic vegetation were made as well.

- ^{137}Cs analyses on all vegetation and soil samples, collected from 1991 through 1994, were completed. The data reveal much higher concentrations of ^{137}Cs in the vegetation growing on the exposed sediments than what has been reported elsewhere. Statistical analyses of the data are currently underway.

- A mesocosm experiment, in collaboration with B.S. Collins and R.R. Sharitz, was conducted to determine how changes in water quality and fluctuating water levels will affect ^{137}Cs uptake and plant community structure on Par Pond. Results of the experiment are relevant to DOE and should help address issues related to the long-term management of the reservoir.

- Three modeling experiments were performed for BIOMOVS - II. The international modeling exercise is examining the various sources of variation among model predictions. A reduction in this variation would mean less conservative model predictions, more precise results, and thus a less conservative approach to cleanup.

- Experiments were conducted on the transfer rates of Cs and Sr between Par Pond sediments to the water column. Parameterizing this transfer is critical to the accurate prediction of Cs dynamics within the system because >95 % of the Cs is bound to the sediments. The work is being conducted by a student from Colorado State University.

- An exhaustive quality control check was completed on all data collected between June 1991 and the start of refill in August 1994.

- Research was initiated on Pond A, the first settling basin coming out of R-Reactor along R canal as it proceeds to Pond B and Par Pond. The work is conducted in collaboration with Colorado State University and Westinghouse Savannah River Company. An inventory of the radionuclide contamination in the system is being done and a spatial distribution of dose from Pond A sediments using TLDs is being conducted.

- Educational training in radioecological studies at the Par Pond Laboratory has involved students from Colorado State University, Emery University, Paine College, Georgia Institute of Technology, University of South Carolina, and Florida State University. Collaborative

efforts have begun with numerous colleagues in the United States and abroad, including scientists from Sweden, Switzerland, Spain, Russia, Ukraine, Belarus, United Kingdom, Belgium, Germany, and Canada. Outreach efforts into the local community have included a workshop on radioecology and one on science policy and risk analysis.

Radionuclide Environmental Chemistry

S.B. Clark

The inventory and speciation of radioactive contaminants play a major role in predicting their fate and transport in various ecosystems. Knowledge of the level of contaminants as well as an understanding of their site-specific speciation are essential for estimating potential risks and developing cost-effective remediation strategies. Research efforts for this year have focused on the following areas:

1. **Developing new or improved methods** for obtaining data concerning transport processes and mechanisms. Methods include sampling, radiometric, and speciation techniques. Research into the appropriate way to collect representative samples, along with analysis techniques for collected samples, is needed. In many cases, methods and technologies to provide the desired information do not exist, and must be developed before mechanistic studies can be completed.

2. **Determining inventories of radionuclides** in SRS ecosystems. While contamination is known to exist in ecosystems such as Par Pond, F and H seepage basins, old burial grounds, etc., inventories of contaminants are usually estimates based on process knowledge or limited sampling. Additionally, knowledge of naturally occurring radioisotopes can provide mechanistic information. Determination of the inventories is essential to our understanding of transport processes controlling contaminant fate.

3. **Understanding mechanisms of transport** for radionuclides under various geochemical conditions. We are studying hydrologic, sorption, and transformation processes; in addition, the chemical speciation and kinetics controlling transport in time are studied. This type of approach will provide basic mechanistic information that is essential for cost-effective remediation decisions.

Work in methods development has included participation in a nationwide study to develop sequential extraction techniques to determine radionuclide partitioning in sediments and soils. Drs. Sue Clark and Tom Hinton were invited participants in a workshop on the subject by National Institute of Standards and Technology (NIST). In addition, improvements in determination of radiostrontium and transuranic contaminants continues.

We continue to employ these methods to determine radionuclide inventories in ecosystems such as Par Pond. For example, we completed a study on Sr-90 in mollusks and bass skeletons collected from Par Pond. This data set provides information on changes in the levels of radiostrontium in fish and mollusks as a result of drawdown of the reservoir. This work is now being expanded to

include soil and vegetation from that system. Contributions also have been made toward determining inventories for the F/H Area Seepage Basin system and the Burial Grounds.

Finally, we continue to use advanced spectroscopic capabilities to determine mechanisms controlling the transport of radionuclides in these various systems. We have published results that demonstrate the *in-situ* reduction of chromium, technetium and neptunium in saltstone, thereby reducing it's toxicity by several orders of magnitude. Other studies on uranium solubilities have demonstrated that the weathering of the U solid phase can alter its solubility significantly. Uranium transport also is affected by the geochemical controls imposed by the weathering of the soil.

Another noteworthy development is the appointment of Dr. Clark to the National Academy of Sciences Waste Isolation Pilot Plant (WIPP) Committee by the Board on Radioactive Waste Management. The Committee reviews the technical and scientific basis for disposal of transuranic waste at WIPP.

Resuspension and Bioavailability of Contaminated Soil

T.G. Hinton

This research examines the resuspension of contaminated soil particles onto vegetative surfaces. The goal of the program is to determine when inadvertent ingestion of soil by grazing animals might constitute an important pathway of contaminant intake. Research will concentrate on the bioavailability of contaminants attached to soil particles, particularly in determining if sequential extraction techniques can be used to predict biological availability.

Primary results to date:

- Naturally occurring titanium has historically been used as a soil tracer to estimate the mass of soil loaded onto plants. Researchers in Ireland and the United Kingdom have recently questioned the applicability of the Ti technique. The Par Pond laboratory has been examining the particle size dependence of Ti and ^{137}Cs in these same Ireland and United Kingdom soils to determine where the problem lies. Unlike most soils, these problem soils seem to have few particles less than 20 μm in diameter; or more precisely, the small particles have conglomerated with colloids and organic matter so that they behave like larger-sized particles. This causes a bias in the soil loading estimate.

- We have developed a technique to quantify the particle size distribution of soil on surfaces of broad-leaved plants using a plastic stripping method to remove the soil and a computer-coupled microscope to determine the particle characteristics. We hope this information will overcome the bias mentioned above. The technique needs to be refined, however, so that it is appropriate for grasses.

1995 Progress

- The foliar absorption of ^{137}Cs from a resuspended source was quantified and the importance of this pathway was compared to others that contaminate plants.

- A series of chemical extraction experiments was completed comparing the availability of ^{137}Cs at two sites in Ukraine to sediments from Par Pond.

- Experiments were conducted that compared operationally-defined availability of ^{137}Cs from sequential extraction results to true biological availability determined by plant uptake of the contaminant.

- A spatial analysis of Hg distribution within the Hot Arm of Par Pond was conducted.

- Collaborative work with the European community was completed concerning problem soils in the United Kingdom and Ireland. Traditional resuspension measurement techniques have not been successful in these soils.

- The development of a technique to estimate the particle size distribution of soil loaded onto pastures has been plagued with equipment troubles. Plans are underway to complete this work in 1996.

Recent Publications: Radioecology

Askbrant S., J. Melin, J. Sandalls, G. Rauret, T.G. Hinton, R. Vallejo, A. Cremers, C. Vandecasteele, N. Lewyckyj, Y.A. Ivanov, S.E. Levschuk, B.S. Prister, N.P. Arkhipov, A.N. Arkhipov, S.V. Kruglov and R.M. Alexakhin. Mobility of radionuclides in undisturbed and cultivated soils in Ukraine, Belarus and Russia six years after the Chernobyl fallout. Journal of Environmental Radioactivity (in press).

Bajt, S., S.B. Clark, S.R. Sutton, M.L. Rivers, and J.V. Smith. 1993. Synchrotron determination of chromate content using x-ray absorption near edge structure. Analytical Chemistry 65:1800-1804.

Cadieux, J.R., S.B. Clark, R.A. Fjeld, S. Reboul, and A. Sowder. 1994. Measurement of actinides in environmental samples by photon-electron rejecting alpha liquid scintillation. Nuclear Instruments & Methods in Physics Research A 353:534-538.

Clark, S.B. 1995. Separation and determination of isotopes of strontium in calcium carbonate matrices of biological origin. Journal of Radioanalytical and Nuclear Chemistry 194: 297-302.

Hinton, T.G. and F.W. Whicker. A screening model approach to determine probable impacts to fish from historic releases of radionuclides. Science of the Total Environment (in press).

Hinton, T.G. 1993. Variation among model predictions within an IAEA validation exercise. In: *Proceedings on Environmental Transport and Dosimetry.* American Nuclear Society, Charleston, South Carolina, 1-3 September 1993.

Hinton, T.G., J.M. Stoll and L. Tobler. Soil contamination of plant surfaces from grazing and rainfall interactions. Journal of Environmental Radioactivity (in press).

Hinton, T.G., M. McDonald, Y. Ivanov, N. Arkhipov, and A. Arkhipov. Foliar absorption of resuspended ^{137}Cs relative to other pathways of plant contamination. Journal of Environmental Radioactivity (in press).

Hinton, T.G., P. Kopp, S. Ibrahim, I. Bubryak, A. Syomov, L. Tobler, and C. Bell. 1995. A comparison of techniques used to estimate the quantity of soil resuspended onto plant surfaces. Health Physics 68:1-9.

Johnson, W.H., S.M. Serkiz, L.M. Johnson, and S.B. Clark. 1995. Uranium partitioning under acidic conditions in a sandy soil aquifer. In: Waste Management 95. Tucson, AZ.

Johnson, W.H., S.M. Serkiz, and S.B. Clark. 1994. Determination of site specific distribution coefficients of mixed waste contaminants using and in-situ approach. In: 27th Health Physics Society National Meeting: Managing Radioactive and Mixed Waste. Albany, NY.

Lee, J.F., S. Bajt, S.B. Clark, G.M. Lamble, C.A. Langton, and L. Oji. 1995. Chromium speciation in hazardous, cement-based waste forms. Physica B 208&209:577-578.

Seel, J.G., F.W. Whicker and D.C. Adriano. 1995. Uptake of ^{137}Cs in vegetable crops grown on a contaminated lakebed. Health Physics 68:793-799.

Shuh, D.K., N. Kaltsoyannis, J.J. Bucher, N.M. Edelstein, S.B. Clark, H. Nitsche, T. Reich, E.A. Hudson, I.A.M.-A. Rifai, P. Torretto, W. Lukens, K. Roberts, B.C. Yee, D.E. Carlson, A. Yee, B. Buchanan, T. Leighton, W.S. Yang, and J.C. Bryan. 1994. Environmental applications of XANES: Speciation of Tc in cement after chemical treatment and Se after bacterial uptake. In: Proceedings of the Materials Research Society Symposium.

Whicker, F.W., T.G. Hinton and D.J. Niquette.The effects of a partial drawdown on the dynamics of ^{137}Cs in an abandoned reactor cooling reservoir. Science of the Total Environment (in press).

A.5 DATABASE SYNTHESIS

Research Data Archive Activities

R.K. Chesser and J. Heuer

A major activity of the SREL Data Archive Program is the inclusion of new and historical data. Data for 81 studies were received during FY95. Additional data for existing archived studies were also received. Data from several early research activities at SREL (1950s and 1960s) were transferred to computer readable format. As in the past, the manuscript tracking system continued to be the primary means of identifying data for inclusion in the SREL Archive.

One of the purposes of the SREL Data Archive Program is to support scientific research by providing a permanent repository of observational data. During FY95, 3 principal investigators (former SREL employees) were able to replace lost or damaged data with copies from the SREL Archive. In each of these cases, the principal investigators had lost their personal copies of the data including all backup copies. Retrieval of these important data from the SREL Archive saved them considerable time and effort which would otherwise have been required to reenter the data from hardcopy records. Electronic mail was used efficiently to transfer the data and pertinent documentation to the researchers. In each case, the researchers received copies of their data within 6 hours of the request.

Another purpose of the Program is to support the transfer and sharing of information among technical and scientific groups at the SRS. During FY95, a customized catalog of available studies in the SREL Archive was supplied to a Westinghouse researcher responsible for the preparation of a watershed management plan.

The SREL Archive system is a computer-based information system and is, therefore, subject to periodic changes in response to the rapid changes in computer and information technology. SREL is increasingly adopting a more distributed model for addressing laboratory computational and information needs. In support of this change, the SREL Archive System was transferred from the VAX mainframe to a PC as a preliminary step to the eventual transfer to a client-server system. Also, the archive information application has been redesigned to make better use of available resources and to streamline data entry activities.

Studies Included in the SREL Data Archive System during 1995

Study Title	Contact
Radioecological characteristics of R-Reactor cooling water basins	**Hinton**
Woody succession into large old fields (Field 3-412)	**Pinder**
Old field (Field 3-412) vegetation competition study - herbaceous	**Collins**
Study of lability of europium from humic acid	**Clark**
Quantitative genetics of life history traits of mosquitofish	**Meffe**
Quantitative genetics of critical thermal maximum of mosquitofish	**Meffe**
Dynamics of lipid storage of mosquitofish during winter months	**Meffe**
Foraging ecology of the whiptail lizard, *Cnedmidophorus tigris*	**Congdon**
Parasitic nest association in fishes	**Meffe**
Effect of lead exposure in *Helix aspersa*	**Mulvey**
Radiostrontium in $CaCO_3$ matrices of biological origin	**Clark**
Seasonal burning effects on sandhill vegetation	**McLeod**
A technique for measuring venomous snakes	**Gibbons**
Selection of woody spp. for bottomland restoration - wetland restoration	**McLeod**
Modeling of ^{137}Cs uptake by *Trachemys scripta*	**Brisbin**
Flood tolerant spp. on unconsolidated sediment - wetland restoration	**McLeod**
Factors affecting survival of herring gull chicks	**Chesser**
Timing of reproduction and metamorphosis in the crawfish frog	**Gibbons**
Status of scrub and scrub jays in Brevard Co. Florida	**Meffe**
Cesium uptake by water tupelo under innundated conditions	**McLeod**
Resampling of Steel Creek Delta vegetation - 1975	**McLeod**
Effect of temperature and fertility on swamp tree seedling growth	**McLeod**
Effect thermal stress and flooding on black willow	**McLeod**
Effect of thermal regimen and fert. on cattail	**McLeod**
Aristida biomass allocation in oldfield ecosystem	**Collins**
Uranium transport study	**Bertsch**
Effect of sediment instability on growth of bottomland spp.	**McLeod**
Archaeological survey of a Carolina bay	**Taylor**
Incidence of shell disease in turtles	**Gibbons**
Life history of the Sonoran mud turtle	**Congdon**
Study of asymmetry and genetics of *Mus musculus*	**Smith**
Growth of captive king snakes	**Brisbin**
Growth of captive alligators red prepared ration	**Brisbin**
Uptake and concentration of ^{137}Cs in SRS alligators	**Brisbin**
Electrophoretic data from mosquitofish collected in 1994	**Smith**
Seed predation in two species of *Baptisia*	**Sharitz**
Fourmile restoration: transplant techniques	**McLeod**
^{137}Cs levels in gambusia from Pond B - 1991-1992 study	**Brisbin**
Vegetation, biomass, nitrogen pools in spruce fir forest	**Sharitz**

Study Title	Contact
Survey of amphibian egg lipids	**Congdon**
^{137} Cs levels in gambusia from Pond B, SRS - 1987 study	**Brisbin**
Interaction of pyrene with dissolved organic carbon	**Bertsch**
Food and ectoparasites of short-tail shrew - SRS	**Smith**
Ecology and natural history of the brown water snake	**Gibbons**
Population dynamics of snakes and lizards near Ellenton Bay	**Gibbons**
Importance of refugia in drift of stoneflies	**McArthur**
Behavioral profile of free-ranging Anolis	**Congdon**
Comparison of methods of DNA extraction from stream sediment	**McArthur**
Behav., thermal, metab. characteristics of wintering *Anolis*	**Congdon**
Foliar uptake ^{137}Cs by macrophytes in Pond B	**Pinder**
Terrestrial density effects on pond-breeding amphibians	**Gibbons**
Biomass allocation of Aristida tuberc. spikelets	**Sharitz**
Hemosporid community structure in wintering wild turkeys	**Chesser**
Time budget of free-ranging female *Anolis* - Augusta canal	**Congdon**
Genetic structure of *Burkholderia (Pseudomonas) cepacia*	**McArthur**
Development of orthopt. and plant communities during old field succession	**Pinder**
NMR experiments with some florinated organic compounds	**Bertsch**
Genetics of mosquitofish from Altamaha and Ogeechee drainage	**Smith**
Sorption of hydrophob. organic compounds to resid. diesel oil	**Mills**
Ionic tracer movement study	**Bertsch**
GIS study of aquatic turtle nests near a Carolina bay	**Gibbons**
Modelling study of population extinction - effect inbreeding	**Chesser**
Use of total body elect. cond. (TOBEC) to estimate body lipids	**Congdon**
Foliar adsorption of resuspended ^{137}Cs - Chernobyl	**Hinton**
Identification of aquatic *Burkholderia cepacia*	**McArthur**
Relative toxicity of divalent metal ions using Microtox. biol.	**Newman**
Non-conservative anion migration in alluvial sediments	**Bertsch**
Response of mosquitofish to acute environmental stress - family vs. genotype	**Smith**
Metabolism and water flux in free-ranging racers	**Gibbons**
Examination of variation in clutch size for selected species	**Gibbons**
Diel nest temperature and site selection for aquatic turtles	**Gibbons**
Nickel desorption kinetics from hyd. ferric oxide - EDTA	**Clark**
Effect of harvesting on populations of red-eared slider turtles	**Gibbons**
Seedbank and vegetation of a constructed wetland (L-Lake)	**Collins**
Reproduction in the black swamp snake, *Seminatrix pygaea*	**Gibbons**
Life history variation in recently isolated population of *Gambusia*	**Smith**
Effect of translocations on preservation of allelic diversity	**Chesser**
Capture records of pine woods snake on the SRS	**Gibbons**
Habitat selection by eastern blue bird on the SRS	**Brisbin**
Additional data for Bachman sparrow study	**Dunning**

Study Title	Contact
Soil arsenic study	**Onken**
Soil lipid study	**Onken**
Additional data for cottonrat study	
Additional deer data	
Hardegree data	
Columbian ground squirrel study	**Risch**
Wood duck ^{137}Cs uptake study	**Kennamer**

A.6 WILDLIFE STUDIES

Waterfowl Research on the SRS

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

This program was designed to provide basic ecological information on migratory waterfowl populations inhabiting the SRS. In particular, the studies of this program have provided data on population demographics of breeding and wintering species of SRS waterfowl, wintering waterfowl species composition and distributions, and natural history traits related to survival and reproductive success. The data from this program complimented contaminant fate and effects studies being conducted by the program of "Radionuclide Cycling in Vertebrates Inhabiting Contaminated Wetlands" under the direction of the SREL Division of Biogeochemistry by providing detailed waterfowl distributional data from aerial surveys and offsite waterfowl movements and hunter recovery data from the capture, banding, and release of SRS waterfowl; all of these factors are important in assessing SRS contaminant risks to humans who may consume such birds.

The studies conducted by this waterfowl program also have provided assistance to the SREL program "Ecological Effects of the Par Pond Drawdown: Wildlife Studies" by documenting the drawdown effects on wintering waterfowl population numbers and distributions, and similar potential effects on the resident breeding population of wood ducks using nest boxes placed around Par Pond. The results of studies of the birds using nest boxes at this contaminated CERCLA site are compared to data collected from other nest box lines established in uncontaminated "control" habitats elsewhere on the SRS. Without extensive baseline data from these long-term studies of wood ducks, owls, and other species in uncontaminated habitats, information on potential contaminant impacts, such as the occurrence of genetic abnormalities that were recently discovered in screech owls using wood duck nest boxes in Par Pond, would be difficult if not impossible to interpret.

Future studies will continue to document SRS waterfowl population sizes, spatial distributions, and basic ecology, which are particularly relevant to the continued assessment of contaminant effects on these waterfowl and risks to human consumers. Such studies will be necessary at Par Pond for at least one to two years following that reservoir's refill in order to assess the impacts of proposed fluctuating water levels there. Nest boxes at Par Pond also will continue to be monitored for the occurrence of possible genetic defects in SRS owls, waterfowl, and other wildlife species. Additionally, similar waterfowl population ecology studies likely will increase in emphasis at L-Lake and the lower Steel Creek drainage if the decision is made to drain that reservoir. Future plans also include collaborative efforts with other SREL programs to develop GIS-based approaches to integrate much of this program's data with spatially-explicit contaminant information for SRS reservoirs.

Genetic and Demographic Analysis of White-tailed Deer

M.H. Smith and R.K. Chesser

Studies on the population ecology and population genetics of the SRS deer herd in the context of plant operations. In order properly to assess any effects of human influences on a wildlife species, the range of natural variation in both time and space must be assessed. The focus of this research

has thus been threefold. First, to attempt to fill any gaps in our knowledge of the ecology and genetics of the SRS deer herd; second, to analyze the variation of ecological and genetic parameters in time and space for the SRS deer herd; and third, to place the SRS deer herd in the proper geographic and temporal context by extending our analyses beyond the spatial boundaries of the SRS and backward in time before modern anthropogenic factors affected the deer herd. In addition, the SRS deer herd is being used as an example to extend both theoretical and practical aspects of wildlife ecology and management.

Several gaps in our biological knowledge of the SRS deer herd have been filled over the past year. One of the most important aspects of the natural history of any organism for both population ecology and genetics is a detailed understanding of the reproductive biology of the organism. A recent paper by Rhodes and Johns (1993) analyzes the relationship between genetic variability and conception date in deer collected on the SRS. Recent advances in stress ecology indicate that organisms may have a suite of generalized responses to environmental stress, whether that stress is of human origin or not. Analyses that use fluctuating asymmetry as a measure of stress in deer have been completed. These analyses are aimed at identifying age related changes in the effects of stressors, correlations between anthropogenic and other stressors, and the relationship of the effects of stressors on females to the development and survival of their offspring.

Populations of organisms are not static in time or space, especially large, vagile vertebrates. The SRS deer herd provides a unique opportunity to study such changes because of the length of time that the herd has been under study. A paper released during the last year (Smith *et al.* 1990) indicates that long-term studies of large vertebrates are important for achieving the proper analysis of ecological and genetic trends and properly to assess human impacts on those populations. A paper currently in review by *The Journal of Heredity* (Novak and Smith, *in review*) illustrates that correlations between genetic loci can exhibit a large range of variation and this variation can be used to indicate periods when unique events may be impacting a species.

The previous data cannot be reliably used to make inferences regarding the impacts of plant operations on the SRS deer herd until they are placed in the proper spatial and temporal context. Two papers published during the last year help to place the SRS deer herd in a larger spatial (Leberg *et al.* 1994) and temporal (Purdue and Reitz 1993) context. A paper recently submitted to the journal *Science* has used genetic data from allozymes and mitochondrial DNA to look at the genetic structure of deer populations in Georgia and South Carolina including the SRS deer population. This work is being expanded to include mini-satellite DNA analysis to provide finer scale resolution of spatial genetic patterns. The result of our analyses is that the genetic structure of the SRS deer population does not appear to have been affected by plant operations.

The SRS deer herd also is being used as a unique example of a population that has been studied ecologically and genetically for an extended period of time. This allows it to be used for extending both ecological theory (Smith and Risenhoover 1993) and for studying the effects of wildlife management practices (Smith and Rhodes 1993). An invited paper has just been completed for the journal *Forest Genetics* that reviews the implications of genetic heterogeneity for wildlife management and conservation biology. The SRS deer herd is used as the principal model for the application of ecological and genetic data in the management of wildlife species.

During the last year we also have continued to gather data from the annual deer hunts on the SRS. This database has been used to provide population estimates, historical population trends and

population projections to SRFS personnel when requested. The information in this database is crucial for continued enlightened management of the SRS deer herd.

Population Ecology of Turtles at Ellenton Bay

J.W. Gibbons

As human populations and their related activities have increased, natural habitats all over the globe have been destroyed or compromised. Entire populations of many species have been eliminated or reduced. Establishing population trends of species in habitats upon which the level of human impact is equivocal is quite difficult. Protected research areas on the Savannah River Site have allowed us to assess annual population levels of resident species of turtles for more than two decades. Such long-term study has allowed us to monitor population fluctuations that occur as a result of normal extremes of environmental variation in several different habitat types. The short-term funding experienced by many researchers may result in accurate information for the short-term but may give an incomplete picture of the cyclic trends experienced by many longer-lived animals. The continued funding we have received at SREL due to DOE's commitment to SRS research has had a major impact on our knowledge of life history characters and phenomena in long-lived reptiles, many of whom do not reproduce until five years of age or older, and who then continue to reproduce beyond the age of 30 years. Such long-term studies are key to our understanding of the environmental sources of selection on reptile life history ecology.

From 1994 through 1995 our major emphasis has been a continuation of turtle ecology studies at Ellenton Bay and surrounding aquatic areas, which were initiated in 1967 and have been continued intermittently since then. Drought conditions of the 1980s and the subsequent flooding in the winter of 1992-93 have allowed us to compare the responses of several sympatric species to these environmental extremes. The common mud turtle (*Kinosternon subrubrum*) and the yellow-bellied slider turtle (*Trachemys scripta*) are the two most abundant and intensively studied species within the Ellenton Bay system. Life history data also have been gathered on eight other species which occur there in smaller numbers. Turtles were measured, marked (or existing ID code was recorded), and released at the site of capture. Temporary and permanent aquatic habitats near Ellenton Bay were trapped (as they have been in the past) to gain more insight into the movement between, and utilization of, different wetlands by co-existing species of freshwater turtles with contrasting life history strategies.

Nesting and reproductive information also is being gathered at Dry Bay, a Carolina Bay near Ellenton Bay. These data will augment those from the previous year which was virtually the first comprehensive study of the species which nest at Ellenton Bay. Research on both the movement and nesting behavior of these turtles is relevant to reaching an environmentally rational definition of wetlands that includes the surrounding terrestrial habitats.

Wildlife Studies

M. H. Smith

Organisms live within a constantly changing environmental framework that provides the overall structure of the ecological and genetic components of populations. Human society makes

impacts on the environment that other organisms must respond to. Thus the overall focus of this research has been the understanding of wildlife species population ecology and genetics in response to environmental perturbations. These perturbations may be caused by human activity or by nonhuman influences. The anthropogenic perturbations are both a result of plant operations and the broader scale changes brought about by human society. This research, while primarily focusing on impacts due to plant operations, includes both nonhuman perturbations and human induced changes outside of plant operations. This allows the impacts of plant operations to be placed into a realistic ecological perspective on an appropriate spatial and temporal scale.

Population studies on the SRS have utilized a wide range of wildlife species. During the last year, papers describing the genetic structure of American coots wintering on the SRS (McAlpine *et al.* 1994) and the reproductive biology of a marbled salamander population (Sever *et al.* 1995) have appeared. The scope of our analyses has been broadened to include the use of flow cytometric analysis to examine genetic effects of environmental stress (Fisher *et al.* 1995). A paper analyzing the genetic structure of wild turkey populations on the SRS has been accepted for publication in The American Midland Naturalist (Boone and Rhodes *In Press*) and another paper using mosquitofish as a model organism to understand genetic response to acute environmental stress also has been accepted for publication (Kandl and Thompson *In Press*). The results of additional experiments on the effects of environmental perturbations on the genetic structure of mosquitofish populations are currently being prepared for publication. Experiments are continuing which have expanded the scope of analysis of genetic effects to quantitative characters and also to the response of organisms to chronic stress, using mosquitofish as the model organism.

The scope of this research also includes broader-scale studies in order to put the results of our experiments in a definable ecological context. Papers have been published over the last year examining the genetic structure of turkey populations in the eastern United States (Leberg *et al.* 1994), the temporal pattern of sex ratios in American and European species of moles (Hartman 1995), and the effects of developmental asynchrony on the evolution of tropical birds (McDonald and Smith 1994). Papers have also been published that allow us to place our mosquitofish experiments in a better regional (Hernandez-Martich *et al. In Press*) and global perspective (Scribner and Avise 1994). These broader scale studies allow us to place the variation we see in wildlife populations on the SRS into the proper spatial and temporal framework so that these changes can be compared to changes in populations existing in other areas remote from the effects of plant operations.

Recent Publications: Wildlife Studies

Boone, M.D. and O.E Rhodes, Jr. Genetic structure among subpopulations of the eastern wild turkey (*Meleagris gallipavo sylvestris*). American Midland Naturalist (in press).

Buhlman, K., T.K. Lynch, J.L. Greene, and J.W. Gibbons. Prolonged egg retention in the chicken turtle, *Deirochelys reticularia*. Herpetologica (in press).

Fisher, S.K., J.T. Lingenfelser, C.H. Jagoe and C.E. Dallas. 1995. Evaluation of the effects of cryopreservation of isolated erythrocytes and leukocytes of largemouth bass by flow cytometry. Journal of Fish Biology 46:431-441.

Gibbons, J.W. and D. Jackson. *Deirochelys reticularia*, in Conservation Biology of Freshwater Turtles, edited by Anders Rhodin (in press).

Gibbons, J.W. and Klemens. *Kinosternon subrubrum* (lacepede), in Conservation Biology of Freshwater Turtles, edited by Anders Rhodin (in press).

Hartman, G.D. 1994. Seasonal effects on sex ratios in moles collected by trapping. American Midland Naturalist 133:298-303.

Hernandez-Martich, J.D., J.M. Novak, M.H. Smith and P.E. Johns. Genetic structure of mosquitofish populations in the Altamaha and Ogeechee drainages of Georgia: reporting an undescribed form in the Ocmulgee River. Biochemistry and Systematic Ecology (in press).

Leberg, P.L., P.W. Stangel, H.O. Hillestad, R.L. Marchinton, and M.H. Smith. 1994. Genetic structure of reintroduced wild turkey and white-tailed deer populations. Journal of Wildlife Management 58:698-711.

Kandl, K.L. and A.J. Thompson. Do family effects obscure inbreeding and genotype effects?: Responses of eastern mosquitofish (*Gambusia holbrooki*) to acute environmental stress. Canadian Journal of Fisheries and Aquatic Sciences (in press).

Leberg, P.L., P.W. Stangel, H.O. Hillestad, R.L. Marchinton, and M.H. Smith. 1994. Genetic structure of reintroduced wild turkey and white-tailed deer populations. Journal of Wildlife Management 58:698-711.

McAlpine, S., O.E. Rhodes, Jr., C.D. McCreedy and I.L. Brisbin. 1994. Genetic structure in a wintering population of American Coots. Wilson Bulletin 106:738-743.

McDonald, M.A. and M.H. Smith. 1994. Behavioral and morphological correlates of heterochrony in Hispaniolan palm-tanagers. The Condor 96:433-446.

Purdue, J.R. and E.J. Reitz. 1993. Decrease in body size of white-tailed deer (Odocoileus virginianus) during the late Holocene in South Carolina and Georgia. Pages 281-298 in R.A. Martin and A.D. Barnosky, (eds.) Morphological Change in Quaternary Mammals of North America. Cambridge University Press. Cambridge, UK.

Rhodes, O.E., Jr. and R.S. Johns. 1993. Relationships between heterozygosity and conception date in white-tailed deer from South Carolina. Pages 119-125 in I. D. Thompson, (ed.) Forests and Wildlife. Towards the 21st Century, Vol. 1. Proceedings of the XXI IUGB Congress. International Union of Game Biologists. Halifax, Canada.

Scribner, K.T. and J.C. Avise. 1994. Cytonuclear genetics of experimental fish hybrid zones inside Biosphere 2. Proceedings of the National Academy of Sciences (USA) 91:5066-5069.

Sever, D.M., J.D. Krenz, K.M. Johnson and L.C. Rania. 1995. Morphology and evolutionary implications of the annual cycle of secretion and sperm storage in Spermathecae of the salamander *Ambystoma opacum* (Amphibia: Ambystomatidae). Journal of Morphology 223:35-46.

Smith, M.H. and O.E. Rhodes, Jr. 1993. Genetic applications in wildlife management: An introduction. Pages

110-112 in I. D. Thompson, (ed.) Forests and Wildlife. Towards the 21st Century, Vol. 1. Proceedings of the XXI IUGB Congress. International Union of Game Biologists, Halifax, Canada.

Smith, M.H. and K.L. Risenhoover. 1993. Association between production of offspring and genetic variability in cervids. Pages 113-118 in I. D. Thompson, (ed.) Forests and Wildlife. Towards the 21st Century, Vol. 1. Proceedings of the XXI IUGB Congress. International Union of Game Biologists, Halifax, Canada.

Smith, M.H., K.B. Willis, and P.E. Johns. 1990. Spatial-genetic variation in a white-tailed deer herd. Pages 80-84 in S. Myrberget, (ed.) Proceedings of the 19th Congress of the International Union of Game Biologists. Volume 1: Population Dynamics. Norwegian Institute for Nature Research, Trondheim, Norway.

A.7 AQUATIC COMMUNITIES OF RESERVOIRS AND PONDS

Invertebrate Production and Dynamics in Natural Wetland Ponds

B.E. Taylor and D.L. Leeper

Among the diverse and extensive aquatic habitats of the SRS are several hundred Carolina bays and other isolated wetland ponds. Because many of these ponds dry seasonally, most of the larger, longer-lived consumers in the ponds are either amphibious, such as frogs, toads, and salamanders that live and feed in the pond for only part of their life cycles, or terrestrial, such as waterfowl that visit the pond to feed. Many aquatic insects are also effectively amphibious. In either case, animal production from the pond is exported to terrestrial habitats, while terrestrial production, mainly plant litter, accumulates in the pond to be used by the aquatic animals. One of the long-term goals of this program is to elucidate the role of these isolated wetland ponds in local energetic economies. Another long-term goal is to understand the adaptations that enable a great diversity of aquatic invertebrates to survive the irregularly seasonal hydrologic variation of these ponds. The information from these studies contributes to our ability to assess the potential effects of changes in land use or climate on wetland ponds and to develop a sound basis for conservation or management plans.

Rainbow Bay was chosen for a 2-year study of benthic invertebrates so that results would complement extensive records on dynamics and production on planktonic invertebrates and amphibians. Sampling for the study was completed in 1993, and analyses of the samples and data will be completed in 1995. The benthos was dominated by oligochaete worms (usually >40% of the biomass) and larvae of chironomid flies. Although the aquatic community of the pond is unusually rich in species, its productivity is low. Production of oligochaetes was 62 kg in 1992 and 31.8 kg in 1993; production of chironomids was 19.7 kg in 1992 and 2.7 kg in 1993. Benthic production is about twice as great as planktonic production. The chironomids are particularly important for the salamanders *Eurycea quadridigitata* and *Notophthalmus viridescens*, which feed heavily on chironomids during the latter part of their larval stages.

In two separate projects, data has been synthesized from extensive SREL studies to construct computer-based models of pond populations. These models can be used as tools to explore the potential consequences of management decisions affecting the ponds and their surroundings.

B. E. Taylor and D. E. Scott developed a model to study population dynamics of the marbled salamander *Ambystoma opacum* using data and insights derived from laboratory experiments, eight years of field experiments, and numerous observations of natural populations. The model includes density-dependent larval survival and size at metamorphosis, density-independent survival in other stages, and size- and age-dependent terrestrial growth and reproduction. Terrestrial females are tracked individually. Applied to a natural population (at Ginger's Bay) with low annual recruitment (range 0.7-7.9 metamorphs per breeding female over 9 yr), results of the model indicate that either high terrestrial survival (>0.7 yr^{-1}) or immigration is required to maintain the population and that the population is extremely sensitive to conditions affecting terrestrial survival.

V. L. Medland, a doctoral student at University of Georgia, developed a model to study dormancy of zooplankton in wetland ponds. Resting stages enable strictly aquatic animals, such as copepods, cladocerans, and ostracods, to survive the hydrologic vagaries of these habitats. Parameters for the model are derived from field and experimental studies at Rainbow Bay. The model

includes a spatially explicit description of the basin, so that the effect of fluctuating water level on deposition and reactivation of resting stages can be tracked. The model attempts to predict the effect of changes in the hydrologic regime due to weather or modification of the basin on composition and dynamics of the zooplankton.

Zooplankton Biogeography

B. E. Taylor and A. E. DeBiase

The microcrustacean assemblages in the natural wetland ponds of the Savannah River Site show an extraordinary diversity, analogous to that of the aquatic insects in Upper Three Runs Creek. Before work was begun, virtually no information was available about microcrustaceans in these pond habitats on the Savannah River Site or elsewhere in the region. The goals of this program have been to characterize species composition of planktonic microcrustaceans in these ponds through a series of surveys and to test for associations between occurrences of species and geographic, environmental, and ecological factors. Artificial ponds and reservoirs have been included in some of the studies. These data provide baseline characterizations of the aquatic communities on the SRS.

No new field sampling was undertaken in 1995, and manuscripts from earlier studies are being completed. The most common calanoid copepod of the Carolina bays and other wetland ponds on the SRS has been diagnosed as a new species, and the name *Diaptomus atomicus* has been proposed for it.

Secondary production and trophic pathways in reservoirs

B. E. Taylor and D. A. Leeper

For the benthic and planktonic invertebrates, results from the large base of existing data for Par Pond and other SRS reservoirs will be synthesized to estimate magnitudes of major trophic pathways under a range of hydrologic conditions. These results can be used to predict effects of management decisions for the reservoirs on ecological processes such as the movement of contaminants.

An expanded analysis of zooplankton dynamics in Pond C was completed during a period of intermittent reactor operation. Rapid recolonization occurred after each episode of reactor operation. Birth and population growth rates and spatial distributions were used to infer which taxa recolonized from refuges within Pond C and which recolonized from external sources. Although this specific thermal stress no longer occurs on the SRS, the dynamics of the recovery process may provide insight toward managing other stressors of reservoir communities.

Vegetation Development and Contaminant Uptake in Par Pond

B. Collins, T. Hinton, and R. Sharitz

Management strategies, such as the decision to refill Par Pond, the choice of input water, and the maintenance of stable or fluctuating hydrology, influence vegetation development and contaminant transport. To determine the influence of water source (Par Pond, Pond B, Savannah River) and hydrology (stable, fluctuating) on development of vegetation from the seedbank and on radiocesium transfers among sediments, macrophytes, and water, sediment cores were removed from

the original waterline at 13 locations around Par Pond. Cores were placed in pots and given a water source and hydrology treatment for one growing season. Plant species composition in the pots will be censused at the end of the 1995 growing season and biomass and radiocesium content of plants, water and sediment will be determined.

Recent publications: Aquatic communities

Boileau, M.G., and B.E. Taylor. 1994. Chance events, habitat age, and the genetic structure of pond populations. Archiv für Hydrobiologie 132: 191-202.

Gaiser, E.E. 1994. Seasonality, substrate preference and attachment sites of epizoic diatoms on cladoceran zooplankton. Journal of Plankton Research 16: 53-68.

Leeper, D.A., and B.E. Taylor. 1995. Plankton composition, abundance and dynamics in a severely stressed cooling reservoir. Journal of Plankton Research 17: 821-844.

Leeper, D.A., and K.G. Porter. Toxicity of the mixotrophic chrysophyte *Poterioochromonas malhamensis* to the cladoceran *Daphnia ambigua*. Archiv für Hydrobiologie (in press).

Monger, B.C., J.M. Fischer, B.A. Grantham, M.L. Medland, B. Cai, and K. Higgins. Frequency response of a periodically forced three trophic level food chain model with time delayed recruitment: implications for abiotic-biotic coupling. *In* H. Caswell and V. Tuljapurkar, editors, Structured Population Models in Terrestrial, Freshwater and Marine Systems (in press).

A.8 SAFETY AND QUALITY ASSURANCE

Quality Assurance Program
D.R. Burrows

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

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

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

Environmental Program
V. Harper

In September 1993, the Department of Energy conducted a comprehensive baseline environmental audit of the Savannah River Ecology Laboratory. As a result of that audit, several new environmental compliance initiatives have been undertaken by SREL.

Through FY95 the DOE field office has conducted approximately 30 assessments of the SREL environmental program. DOE assessments have shown that SREL demonstrates effective environmental management in the areas of affirmative procurement, waste minimization, pollution prevention, NEPA, and EPCRA Sara Title III reporting.

Laboratory technical personnel have displayed great initiative in improving the SREL recycling program and in maintaining field research areas. This year an assessment of environmental compliance was added to the SREL employees' performance evaluations.

Environmental Health and Safety Program
W.J. Safter

The Savannah River Ecology Laboratory is committed to providing a safe and healthy work environment where risks to the occupational safety and health of its personnel remain as low as is reasonably achievable. This year, several programs were initiated to further that goal.

The SREL Environmental Health and Safety (EH&S) office has played an integral role in the maintenance of existing facilities and in planning for renovations and new construction. Potential physical, chemical, and biological hazards were identified during periodic facilty inspections and corrective actions were initiated through the SREL Work Order system. Additionally, several fume hoods were upgraded, additional safetly showers and eyewashes were installed, laboratory hazards

were identified on new door signs, asbestos hazards were identified and labeled, the 737A fire alarm system was enhanced, and ergonomic hazards were addressed through facility upgrades. As a member of the SREL Facilities Committee, the EH&S Manager is consulted on new construction projects and major renovations. Plans for conference room and laboratory renovations, a new receiving building, a library/office addition, and a new laboratory wing were reviewed.

Annual performance evaluations of SREL personnel now include a measure of safety performance. A new safety infraction policy also was adopted. This policy helps to assure consistency in dealing with personnel who violate accepted policy. A revised safety incentive program also was established.

A major emphasis on increasing safety awareness was undertaken this year. The introduction of a user-friendly in-house electronic mail system enhanced safety-related communication. This system was used to provide lessons learned information, product safety alerts, hazard alerts, and training opportunity information in a timely manner. The use of the "Grapevine" and "Grapeleaf" publications to disseminate additional information continued. Additionally, safety articles of interest were posted on the safety bulletin board on a weekly basis. Brief safety reminders were placed on personnel pay envelopes, safety pamphlets and periodicals were made available, a safety lending library and resource room were established, and safety information was placed in break rooms and the reception area. A very successful ergonomics fair was sponsored by SREL for the SRS in January. In addition, improvements were made to the already successful Material Safety Data Sheet program.

Formalized training, which includes job-specific training for new personnel, has been enhanced. For those personnel who required it, training was provided in firearms safety, driver safety, and boating safety (with additional training for personnel operating air boats and electroshocking boats). Radiation workers were trained under the SRS program with additional training at SREL in x-ray safety and sealed source safety. Training also was offered in first-aid and CPR, wilderness medical, fire prevention, laboratory safety, personal protection, laser safety, and ergonomics. A biweekly safety video series was instituted this year.

DOE and WSRC assessments in radiation area access, NESHAPS, radioactive waste management, environmental radiation, general housekeeping, fire safety, OSHA compliance, ALARA, and RADCON compliance were conducted. Overall, SREL received some of its highest ratings this year. In August, the National Safety Council will conduct an audit of the comprehensive SREL safety program.

Recent Publications: Safety and Quality Assurance

Burrows, D.R. 1995. Quality, compliance and creativity in an ecology research laboratory. Tenth International Conference of the Israel Society for Quality. Jerusalem, Israel.

Burrows, D.R. 1995. The impact of journal publications as a measure of quality. Annual National Energy and Environmental Division Conference, American Society for Quality Control. Tucson, AZ.

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 FY95. 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.

B. SREL WOOD STORK PROGRAM

Wood Stork Foraging and Breeding Ecology

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

Aerial surveys of the Savannah River Swamp System (SRSS) and the Par Pond and L-Lake reservoirs for Wood Storks were conducted from August 5 through October 6 of 1994, and from February 21 through August 31 of 1995. During the Fall surveys (1994), low numbers of storks were observed in the SRSS during 4 of 10 surveys, primarily in Steel Creek Delta. During the early Spring and Summer surveys (1995), low numbers of storks again were observed in the Steel Creek Delta area, as well as in several Carolina bays and other temporally-isolated wetlands on the SRS. Stork prey samples are being collected from many of these sites for future analyses for the presence of contaminants.

The breeding success of storks in the Birdsville and Chew Mill Pond colonies in Jenkins County is being continually monitored since these colonies are the closest (approximately 45 km) sources of storks that might forage on the SRS and at the Kathwood foraging ponds. There were 240 stork nests in Birdsville this year, which produced an average of 1.9 ± 1.4 fledged young per nest. The Chew Mill Pond colony, first formed in 1993, contained 45 stork nests which produced an average of 2.0 ± 1.0 fledged young per nest. This colony was thought to be a "satellite" colony of Birdsville. This year, a stork banded as a juvenile in the Birdsville colony in 1991 was observed nesting in Chew Mill Pond. During July of 1995, Georgia Department of Natural Resources (GDNR) personnel discovered a new colony in Screven County, Georgia, approximately 38 km southeast of the SRS. SREL will monitor this colony to see if it re-forms in 1996, since it also might be a likely source of storks foraging on the SRS.

The Kathwood Lake foraging ponds were made available for the storks on July 5, 1995 when pond 4 was lowered. Storks utilized the ponds for approximatley 40 days, with a single day maximum of 160 storks observed in pond 3 on August 5. Continued studies of nocturnal foraging by storks showed that the birds forage at least as much at night as they do during the daylight or crepuscular hours. Foraging behaviour studies like this will assist in our determination of consumption rates of prey by this species. As in previous years, the majority of storks using the ponds were juveniles (hatched in 1995). While the Jenkins County colonies are thought to be the primary sources of storks using the ponds, in 1988 poor breeding success at Birdsville and high numbers of juvenile storks observed at Kathwood indicated that storks from other colonies also were using the ponds. This year, a juvenile stork banded as a nestling in the Harris Neck National Wildlife Refuge below Savannah, Georgia, was observed foraging in pond 2 at Kathwood. Pond 2 was completely drained in mid-August of 1995 (after the storks had left the area) to help eradicate unwanted species fish (bass & channel catfish) that prey on the bluegill stock as storked forage.

A workshop concerning the role, function and stork use of the Kathwood foraging ponds was hosted jointly by SREL and the National Audubon Society on August 2, 1995. Participants included visiting B.E.S.T./O.R.I.S.E. teachers and educators from two SRS education/outreach programs. This workshop, which likely will become an annual event, allowed the participants to become involved in hands-on research/monitoring while learning about stork ecology and the successful mitigation program at Kathwood.

The SREL Wood Stork Program, in cooperation with GDNR, received funding from the U.S. Fish and Wildlife Service (USFWS) to examine the population genetics of Wood Storks in Georgia and Florida, using molecular techniques. Blood samples were collected from nestlings in 9 colonies in 1994 and 16 colonies in 1995. Molecular genetics analyses are on-going at Texas Tech University. The goal of this research is three-fold: (1) to assess inter-relatedness of colonies to determine whether the storks from the U.S. are "one" population (colonies/regions cannot be distinguised from each other), (2) to determine whether the U.S. population has separated into sub-populations (e.g. coastal vs. interior colonies, etc.), and (3) to determine whether storks can be associated with a specific colony using genetic markers.

In 1995, this program received additional funding from the USFWS to examine the ecology of storks inhabiting the coastal zone of Georgia. Similar to earlier research concerning the Birdsville Colony, determinations were made regarding the breeding success, activity patterns of parent storks, and foraging habitat use at three colonies. Data analyses are on-going.

Recent Publications: SREL Wood Stork Program

Bryan, A.L., Jr. and M.C. Coulter. 1994. Wood stork use of the Kathwood foraging ponds: 1986-1993. Pp. 53-56 in the Proceedings of the Wood Stork Symposium. The Georgia Conservancy, Savannah, GA.

Bryan, A.L., Jr., M.C. Coulter and C.J. Pennycuick. 1995. Foraging strategies and energetic costs of foraging flights by breeding Wood Storks. The Condor 97:133-140.

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.

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

DWPF Construction and an Experiment in Mitigation

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

SREL's research related to construction of the Defense Waste Processing Facility (DWPF) provides DOE with data for compliance with the National Environmental Policy Act, Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands), and DOE guidelines for compliance with Floodplain/Wetlands Environmental Review Requirements (10 CFR 1022). Before construction, the 600-acre DWPF site contained a Carolina bay and the headwaters of a stream. The primary focus of SREL's ecological studies has been to assess the impact of DWPF construction on biota associated with these wetlands, and the effectiveness of mitigation measures undertaken by DOE.

Studies are being conducted before, during, and after construction, in accordance with commitments outlined in the DWPF Environmental Impact Statement. SREL's studies were begun in late 1978, and DWPF construction commenced in late 1983. The DWPF facility is currently undergoing cold testing, the transition between the construction and operation stages. Consequently, SREL's studies should enter their post-construction phase during FY-1996. Current research emphasizes: 1) monitoring the water quality of peripheral streams that were impacted by DWPF construction, 2) understanding the population dynamics of amphibian species so that human-induced population fluctuations can be separated from naturally occurring fluctuations, and 3) studying the role of terrestrial buffer zones around wetlands in maintaining the viability of wetlands biota.

Water quality monitoring has been conducted monthly, with an emphasis on sampling after rainfall. Water samples were analyzed in the laboratory for turbidity, total suspended solids (TSS), specific conductance, and percent ash. SREL studies documented significant impacts of DWPF construction on water quality in the Upper Three Runs Creek watershed. Despite some recovery towards the end of the construction period, water quality parameters remained elevated following rainfall events during FY-1995, necessitating further monitoring.

When DWPF was built, an entire Carolina bay (Sun Bay) was eliminated. Carolina bays are important centers for biodiversity, especially of amphibians. Alternative breeding sites for amphibians were constructed adjacent to the construction site as an experiment in mitigating the loss of Sun Bay. Studies by SREL demonstrated that these "Refuge Ponds" provided partial mitigation of the loss of amphibian breeding habitat. Difficulty in duplicating the hydrological cycle of a Carolina Bay was found to be one factor that limited the success of the mitigation. Changes in the amphibian community at the DWPF construction site and at the Refuge Ponds are being compared to those at a control site, Rainbow Bay. Data from Rainbow Bay have been relevant to separating natural population fluctuations from declines due to human activities around the world as well as on the SRS. Reports of widespread, unexplained declines and disappearances of amphibian populations over the last 20 years have led many to speculate that amphibians are indicators or biomarkers for serious unknown or underestimated impacts of human activities (e.g., ozone depletion). Data from the DWPF control site, Rainbow Bay, have figured prominently in scientific discussions of this issue. Analyses conducted during FY-1995 indicate that population sizes of four amphibian species have

declined at Rainbow Bay over the last 16 years, whereas numbers of one species have increased. SREL research indicates that these changes most likely are natural fluctuations related to climatic variation, predation, competition, and other natural interacting factors. Data from Rainbow Bay represent the longest ongoing multispecies study of amphibian populations in the world.

Results of an experiment completed during FY-1995 suggest that densities in both the aquatic habitat and the associated terrestrial habitat affect population sizes and population dynamics of the narrow-mouthed toad. A companion experiment found that population regulation in the mole salamander occurs primarily in the aquatic habitat. Experimental studies are underway to assess the impact of forest clear-cutting on the growth and survival of pond-breeding amphibians. These research projects are important for understanding the relationship between direct impacts of human activities on wetlands, such as the elimination of Sun Bay, and indirect effects such as the construction activities adjacent to Sun Bay.

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

Dodd, C.K. and D.E. Scott. 1994. Drift fences encircling breeding sites. In: Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, M.S. Foster (eds.). Smithsonian Institution Press, Washington, D.C.

Pechmann, J.H.K. 1994. Population Regulation in Complex Life Cycles: Aquatic and Terrestrial Density-dependence in Pond-breeding Amphibians. Ph.D. Dissertation, Duke University, Durham, North Carolina.

Scott, D. E. 1994. The effect of larval density or adult demographic traits in *Ambystoma opacum*. Ecology 75:1383-1396.

Pechmann, J.H.K. Use of large field enclosures to study the terrestrial ecology of pond-breeding amphibians. Herpetologica (in press).

Scott, D.E. and M.R. Fore. The effect of food limitation on lipid levels, growth, and reproduction in the marbled salamander, *Ambystoma opacum*. Herpetologica (in press).

Semlitsch, R.D., D.E. Scott, J.H.K. Pechmann, and J.W. Gibbons. Structure and dynamics of an amphibian community: evidence from a 16-yr study of a natural pond. In: Long-term Studies of Vertebrate Communities. M.L. Cody and J. A. Smallwood, (eds.). Academic Press, New York (in press).

Whiteman, H.H., T.M. Mills, D.E. Scott, and J.W. Gibbons. Confirmation of a range extension for the pine woods snake (*Rhadinaea flavilata*). Herpetological Review (in press).

D. ENVIRONMENTAL RISK ASSESSMENT

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

Freshwater unionid mussels are one of the most endangered faunal elements in North America (Master, 1990; Williams et al., 1992). The Savannah River adjacent to the Savannah River Site (SRS) and streams draining the SRS property provide habitat for populations of freshwater mussels which are rare (Britton and Fuller, 1979; Davis and Mulvey, 1993) and which may be of concern to SRS operations. The genus *Elliptio is* represented by at least ten species. Our efforts have been directed to the clarification of the occurrence and distribution of these species on the SRS and in South Carolina. Morphological, protein and DNA analyses have been used to evaluate the boundaries of species. Two manuscripts are in preparation which describe the *Elliptio* of the SRS and vicinity. The first manuscript describes genetic and morphological differentiation among species in the genus *Elliptio* and provides a baseline to evaluate the genetic integrity of small, isolated populations of mussels that may be encountered. The second manuscript will specifically discuss *Elliptio folliculata and E. producta.* These species are found on the SRS and vicinity and have been listed as species of special concern.

Red-Cockaded Woodpecker Studies

R.K. Chesser

The objectives of this program are to develop sound ecosystem management models that would facilitate the recovery of endangered species and maintained viable and stable communities. The habitat of the red-cockaded woodpecker, like many endangered species, 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 population sub-units. 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 for species have not been developed. This research program develops methods for reintroduction of species into natural and created habitats, develops methods for maintaining virile and viable populations for indefinite periods of time, assesses alternatives for conserving genetic variation in the species, and investigates the likely outcomes of community structure with various ecosystem management tactics.

This program has published several manuscripts over the past few years that have clearly demonstrated that traditional approaches to conservation genetics for species distributed like the red-cockaded woodpecker are ineffective and likely to result in rapid losses of genetic variation for the species. Tactics for genetic exchange among groups of remaining woodpecker populations have been largely ignored in the predictive nature of traditional models. This program has developed methods for: 1) predicting the utility of genetic exchange on the maintenance of gene diversity and population viability, 2) 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 loss of gene diversity and population viability, 5) documenting the effects of various tactics of genetic exchange,

founder representation, and reintroduction programs on the fate of genetic variation, and 6) documenting that holistic approaches to ecosystem management are necessary to not only maintain threatened and endangered species but also to maintain consistently productive communities of organisms. Our studies have shown that knowledge of the interdependency of species in a community is crucial for predicting the effects of human impacts upon the long-term stability of a community.

Field studies investigating the movements and population characteristics of flying squirrels on the Savannah River Site have shown that it is unlikely that flying squirrels and red-cockaded woodpeckers will compete for nesting habitats. This absence of competition is particularly evident when considering artifical nest boxes constructed to augment natural cavities. As with similar studies that have been begun by Dr. Peg Mulvey, we should strive to incorporate relevant molecular techniques that enable all of the researchers within the division to utilize modern molecular methods to address specific hypotheses in ecological research.

Recent Publications: Endangered Species

Bandoni, S.M., M. Mulvey and E.S. Loker. 1995. Phylogenetic analysis of eleven species of *Biomphalaria* Preston, 1910 (Gastropoda: Planorbidae) based on comparisons of allozymes. Biological Journal of the Linnean Society 54:1-27.

Mulvey, M., M.C. Newman and A. Beeby. Genetic and conchological comparison of snails *(Helix aspersa)* differing in shell deposition of lead. Journal of Molluscan Studies (in press).

Bandoni, S.M., M. Mulvey and E.S. Loker. Intraspecific and interspecific patterns of allozyme variation among species of *Biomphalaria* Preston, 1910 (Gastropoda-Planorbidae). Biochemical Systematics and Ecology 54:1-27.

D.2 FISH

Ecological Risk Assessment and Stream Restoration to Thermal Flow Disturbance

G.K. Meffe

The effects of effluent release on fish community structure and function are being addressed, using Fourmile Creek and Pen Branch as replicate disturbed sites, and Upper Three Runs Creek and Meyer's Branch as replicate control sites. Fishes in these streams are being studied at several levels of organization, including community structure, interspecific interactions, species-specific habitat use, and individual physiology.

Community and Habitat Alteration Due to Past Thermal and Flow Disturbance: Intensive sampling of stream fish communities and habitat structure began in these four streams in 1994. To date, four seasonal samples have been taken, and preliminary analyses have begun. Each seasonal sample consists of 48 sites distributed among the four streams. Sites were chosen to include major habitat types in the selected reaches of each stream. These surveys consist of multiple-pass electroshocking, identification and counting of collected individuals of all species, measurement of individuals of most species, and return of fish alive to the stream. Surveys are conducted in January (winter sample/prespawning for early season spawning fishes), May (pre-spawning for summer spawning species/ post spawning for early spawners), and September (post spawning for summer spawning species). Taking collections during these times maximizes the utility of our data for examining demographic patterns and seasonal patterns of habitat use.

Within each of the 48 sites, at least five permanent habitat transects have been established, upon which detailed information is collected, including channel dimensions, depth profiles, substrate types and firmness, presence and type of woody debris, presence of submergent and emergent aquatic vegetation, canopy cover (amount and type), water velocity, pH, dissolved oxygen, and turbidity/sediment loads. Our constant elevation markers will help determine stream bed scouring and sediment deposition over time. Sediment loads in the water columns of each stream during flood events also will be analyzed.

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

Responses of Community Structure to SRFS Restoration Activities: The SRFS has divided the disturbed Pen Branch stream corridor into a longitudinal series of cross-sections that mark unmanipulated control areas and experimental restoration sites. The experimental areas have been herbicided to kill existing vegetation, burned to remove ground cover, and replanted with native hardwood trees. Twenty-five of the 48 study sites are distributed among these control and experimental sections of Pen Branch, which is allowing an analysis of the effects of restoration efforts on the fish communities. Data that had been collected prior to vegetation manipulation have established a baseline of the fish communities before experimental restoration, and data from

undisturbed streams are serving as a target endpoint of a successful restoration. To date, no significant effects of restoration activities have been recorded, but it is too early to expect such effects, which should take several more years to begin to manifest themselves.

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

- Habitat shifts and spawning needs of individual species: Habitat shifts and seasonal spawning movements of individual species for all stages of their life cycle are pertinent both to understanding community function and to monitoring recovery toward endpoints. Spawning and nursery areas, as well as over-wintering areas, are being identified for *Lepomis auritus, L. punctatus, L. marginatus,* and *Notropis cummingsae*, four common species in these streams. Initial work for this phase began this year. Habitat shifts by individual species then will be compared among the four study streams, and the tolerance of individual species to habitat modification determined.

- Interspecific spawning interactions and demography of selected species: We have learned that dusky shiners (*Notropis cummingsae*) migrate into slow, still waters to spawn on nests of redbreast sunfish (*Lepomis auritus*), and that the interaction is probably obligatory for the shiner. We also have discovered that, while in the host sunfish nests, the shiners feed on embryos and larvae, selectively eating host offspring. We have begun to extend these studies in three ways: a) we are documenting stream-wide patterns of nesting activities as a function of previous disturbance (braided, disturbed streams vs. natural, undisturbed streams) and local habitat structure; b) we are comparing microhabitats of individual nests and their placement among mesohabitats within and among streams by beginning to characterize the local habitat structure (canopy development, aquatic vegetation, woody debris/cover, substrate type, water depth, temperature, distance to moving water, pool characteristics, and surrounding land use), size of nests, nest activity, distance from shore, and coloniality; and c) we are using the number of nests observed in our study sites along with our community data to analyze demographic patterns of these species. All of these studies began this past year and are progressing well.

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

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

M. Mulvey and M.C. Newman

Bioaccumulation and potential impacts of mercury associated with Par Pond sediments is being assessed in experimental mesocosms with mosquitofish, *Gambusia holbrooki,* as the indicator species. Eight mesocosm pools have been established to evaluate potential long-term, sub-lethal effects. Mercury accumulation in mosquitofish has been determined for fish maintained with Par Pond sediment and experimentally elevated mercury, as well as controls (no added mercury). Allozyme

genotype frequencies have been determined for mosquitofish used to initiate the mesocosm populations. Mosquitofish will be harvested annually. Allozyme frequencies will be assessed to evaluate potential genetic responses associated with the mesocosm conditions. Additionally, when harvested, fish are weighed, sexed and reproductive output of females is determined to evaluate potential impacts on fish. The research will provide an assessment of potential changes in tissue concentrations of mercury and impacts on an indicator that can be used to make decisions regarding remediation options in the Par Pond system

Recent Publications: Fish

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Mulvey, M., M.C. Newman, A. Chazal, M.G. Heagler and L.S. Hales, Jr. 1995. Demographic and genetic responses of mosquitofish *(Gambusia holbrooki* Girard 1859) populations stressed by mercury. Environmental Toxicology and Chemistry 14:1411-1418.

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Newman, M.C. and R.M. Jagoe. bioaccumulation models with time lags: dynamics and stability criteria. Ecological Modeling (in press).

Newman, M.C. Measuring metals and metalloids in water, sediment and biological tissues. In: Ostrander, G.K. (ed.), Techniques in Aquatic Toxicology. Lewis Publishers/CRC Press, Boca Raton, FL.

Weeks, S.C. and G.K. Meffe. Quantitative genetic and optimality analyses of life-history plasticity in the eastern mosquitofish, *Gambusia holbrooki*. *Evolution* (in press).

D.3 ASH BASIN STUDIES

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

C. Rowe, J.D. Congdon, and R.D. Nagle

Coal-powered plants produce steam and electricity for the SRS, and the resulting coal fly ash is stored in open basins on the site. Although coal fly ash is not considered a hazardous waste, some constituents of the ash (primarily heavy metals) may be of environmental concern. Heavy metals present in water, sediments, and soil in and around the deposition basins may be taken up by animals either through direct exposure to contaminants or by ingesting contaminated food items. Bioaccumulation of trace elements may cause a variety of sub-lethal, physiological effects that have the potential to impair growth and reproduction. Accumulation of metals may also affect offspring directly during development or indirectly as a result of genetic damage to parents. A combination of changes in mortality and reproductive success of individuals in impacted populations results in modified population dynamics in the short term, and possibly life-history changes in the long term.

We conducted surveys to determine whether aquatic animals inhabiting the ash basins and the swamp receiving effluent from the basins differed morphologically or physiologically from animals in reference areas. Our surveys indicated that amphibians appear to be exceptionally susceptible to adverse conditions in the basins. Bullfrog tadpoles collected in the basins and drainage swamp contained high levels of arsenic, had severe deformations of the mouth, and had higher resting metabolic rates (measured as CO_2 production and O_2 consumption) when compared to reference animals. When presented with natural algal food in a laboratory experiment, tadpoles with mouth deformations grew significantly more slowly than those with normal mouths. We have not observed morphological effects on the other common frog of the ash basins (the green treefrog). However, we have found greater resting metabolic rates (CO_2 production) in juvenile green treefrogs collected from the ash basins than in those from a reference site.

It appears that increased metabolic rates in amphibians in the ash basins reflects an energetic "cost" that is not experienced by animals inhabiting reference sites. We are currently attempting to identify the possible source of this cost to the animals by quantifying damage to DNA in the tadpoles, since repairing damaged DNA would require energy that otherwise could be allocated to normal processes in the organism. We also plan to analyze tadpoles for the presence of specific proteins that are formed only under stressful conditions and which may be energetically intensive to manufacture. While attempting to explain the cause of the increased metabolic rates in ash basin amphibians, we will also test the effects of this phenomenon on rates of growth of tadpoles, since growth rate influences the duration of the aquatic larval period and thus exposure to aquatic predators and competitors.

Several other projects are currently underway to investigate possible influences of contaminants associated with the ash basins on biota in the surrounding terrestrial habitats. We have incubated eggs of the yellow belly slider turtle in soil from the ash basins and a reference site and will determine the amount of metals that passively entered the eggs during incubation and the

physiological effects on the hatchlings. We are monitoring growth of juvenile anole lizards in experimental terraria containing soil from the ash basins and a reference site. We also are examining the transfer of heavy metals from ash basin soil to grass to herbivorous insects in experimental terraria.

In the next several months we will place juvenile bluegill sunfish in the ash basins and reference sites to examine growth and uptake of metals. We also will place bullfrog tadpoles (collected from unpolluted areas) in cages in the ash basins and in reference sites in an attempt to induce the physiological and morphological responses identified in our field surveys. We plan to continue collecting aquatic and terrestrial organisms to determine contaminant uptake in organisms in or near the ash basin.

E. ECOSYSTEM ALTERATION BY CHEMICAL POLLUTANTS

These studies in biogeochemical ecology and water quality provide information necessary for making environmental protection and natural resource management decisions based on radioecological and chemical perturbations of various ecosystems. Studies focus on the fate and effects 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

Innovative Uses of Coal Combustion Residues

D.C. Adriano, J. Weber, A. Chlopecka, and C. Sherony

This program was initiated with a major goal of investigating the release and biogeochemical cycling of contaminants from coal pile and ash basins, particularly as they relate to potential contamination of soils, surface waters, and groundwaters. Results have been analysed and synthesized as to the extent of contamination in soil, groundwaters, and adjacent vegetated areas. It is now known that runoff effluents from coal piles at the SRS, particularly in the D Area, are contaminating the groundwaters below. An off-shoot from this program was established in 1994 on the Mason's Tree and Turf Farm in Beech Island, South Carolina. The main purpose of this project was to determine the effectiveness of applying massive amounts of fly ash (up to 10 centimeters surface applied and incorporated into the soil) in enhancing the growth and performance of turf species in alluvial soils that may have some undesirable soil-plant-water relations. However, the success of this technique was contingent on sustaining desirable water quality underneath the treated area. Results to date indicate that no detrimental effects on the turf species were observed and that better soil-plant-water relations were obtained by increasing the water holding capacity of the soil and providing a better substrate for the roots. This project is continuing..

Another project was begun at the Columbia Metropolitan Airport, using an 18-acre borrow pit. This reclamation project was precipitated by massive sedimentation of a near-by road from the borrow pit runoff, which had been posing traffic hazards. To stop the severe erosion from the borrow pit, which was largely non-vegetated due to infertile soil conditions, the project was initiated as a multigroup activity between industry, the Soil Conservation Service, SREL, and SC DHEC. This reclamation project consists of two parts --- an experimental plot where treatments included various rates of fly ash and chicken manure, either singly or in combination, and the rest of the area as a demonstration to indicate the potential significance of the fly ash as a soil quality enhancer. The plot treatments included fly ash rates up to 10 centimeter of surface applied material and chicken manure rates to provide 160 lbs per acre of nitrogen. Data to date indicate that massive applications of weathered fly ash have no adverse effects on plant growth (mixed culture of panic grass, lespideza, lovegrass) which is consistent with the results from the Mason's Turf Farm in Beech Island. Results also indicate that the chicken manure enhances plant growth substantially, apparently much better than inorganic commercial fertilizers. The results from the turf farm and the airport project should be beneficial to SC DHEC in terms of formulating regulations relative to this waste by-product for agricultural lands and physically degraded areas.

Soil Remediation and Restoration: Organic Contaminants

G. L. Mills and G. Voos

Several remediation technologies are currently available to clean up contaminated soils, sediments, and groundwaters. These technologies include the separate and integrated application of incineration, air-stripping, pump and treat methods, and bioremediation. Selection of a treatment strategy is based on its effectiveness for the particular contaminants, site specific criteria in

implementation, and costs for both startup and operation. Remediation can be performed by excavating and treating contaminated materials either on-site or at a remote location (*ex situ*) or by treating the contaminated soils and sediments in place (*in-situ*). The application of *in-situ* remediation technologies has the advantage of eliminating the costs associated with excavation, transportation, and disposal, as well as reducing the exposure of mobilized contaminants to humans and the environment. In addition, *ex situ* remediation of some sites may be impractical because of the areal size or depth of the wastes or because access to the material may be limited by buildings or other structures.

Bioremediation has been demonstrated to be an effective technology for treatment of many organic contaminants. The engineered *ex situ* bioremediation of soil contaminated with petroleum products, referred to as land farming, is now well established and is used in the recently constructed sOils facility located in D-Area on the SRS. However, the implementation of *in situ* bioremediation, although promising, has not been widely utilized in the cleanup of subsurface vadose and aquifer sediments. There is a critical need for additional information regarding both environmental variables to predict and control bioremediation technology and optimization of the engineering process. These problems have recently been identified and reviewed by the Office of Technology Development's "Strategic Plan for Environmental Biotechnology " and a report entitled "Scientific Foundations of Bioremediation: Current Status and Future Needs" by The American Academy of Microbiology. The studies in this research program address several of the priority needs identified in these reports including: (1) development of assessment techniques for effective evaluation of performance of *in-situ* bioremediation, (2) determination of the effects of organic and inorganic co-contaminants on biodegradation, and (3) the effects of environmental and nutritional factors on the degradation rates. The results from these studies will (1) improve the efficiency of existing remediation technology, (2) assist in the selection of appropriate cleanup strategies for various contaminated sites, and (3) facilitate the application of innovative or under-utilized technologies to treat hazardous wastes sites.

Bioremediation facilities that are designed for remediating contaminated soil typically fertilize the soil with inorganic N and P fertilizers. These release N and P into the soil solution, thereby partitioning those nutrients to the polar aqueous phase. Oleophilic fertilizers on the other hand, are designed to adhere to oil and slowly release N and P at the point where microbial activity is most desired. One such oleophilic fertilizer, Inipol EAP 22 was tested in Alaska on various beaches and was found to be more effective than inorganic fertilizers. The oleophilic properties of Inipol EAP 22 are designed to limit its dispersion in water and to hold the nutrients at the hydrocarbon/water interface, or in the case of petroleum contaminated soil, at the soil/oil interface. During the past year we conducted a study using mesocosms to simulate the environmental conditions in the soil bioremediation (sOils) facility on the SRS to compare the rates of diesel fuel degradation in contaminated soil receiving 1) no treatment (control), 2) inorganic N and P fertilizer, or 3) oleophilic fertilizer (Inipol EAP 22). In addition, the relative changes in the ratios of specific hydrocarbon markers were determined to evaluate their use as an index of the petroleum biodegradation.

The mesocosm system consisted of nine plastic tubs (1.5 m x 1.8 m). Each mesocosm contained a drainage bed consisting of 10 cm of clean, coarse sand. The sand layer was overlain with previously mixed diesel contaminated soil (660 kg) which had an average depth of 30 cm. The mesocosms were covered with 60% shade cloth which allowed free exchange of gases and moisture between the ambient atmosphere and soil surface. Moisture levels were maintained at 60% field

water-holding capacity and were monitored and adjusted weekly.

Soil samples were collected prior to treatment application and on days 1, 2, 4, 8, 14, 33, and 64 following treatment application. Soil samples were processed using EPA method 3550 (amended) which employed sonication extraction and solvent exchange. Total extractable petroleum hydrocarbons (TEPH), n-alkanes, and polynuclear aromatic hydrocarbons (PAHs) were quantified using high-resolution gas chromatography (GC) and gas chromatography-mass spectrometry. Comparison of the fraction degraded on day 64 indicated that there were significant differences between the control treatment and the inorganic fertilizer ($p<0.042$) and the Inipol treatments ($p<0.02$). There was no significant difference in the fraction degraded between the two fertilizer treatments.

Though there was no significant difference in the fraction degraded between the fertilizer treatments at the end of the study (i.e., day 64), the slopes of the degradation curves were significantly different. The degradation rate for the Inipol treatment was significantly greater than that for both the inorganic fertilizer ($p<0.004$) and control treatments ($p<0.0004$). The application of Inipol significantly enhanced the degradation of TEPH compared to the control treatment, but was only slightly more effective than the application of inorganic N and P. Analysis of results for the effect of Inipol addition on the degradation of the separate petroleum fractions, including n-alkanes, PAHs and unresolved complex mixture is continuing.

Analysis of hydrocarbon markers indicated the nC17/pristane and nC18/phytane ratios declined over time in each of the treatments. The rate of decline of nC17/pristane was significantly different between the Inipol and control treatments ($p<0.03$), and between the Inipol and inorganic fertilizer treatments ($p<0.004$). Apparent first-order rate constants were calculated for the degradation of nC17, nC18, pristane and phytane. Results indicated that the degradation rate of nC17 was significantly greater than that of pristane in both the control ($p<0.009$) and Inipol treatments ($p<0.012$). The relationship of pristane to total extractable petroleum hydrocarbons (TEPH), among all samples, indicate that there was a decline in isoprenoid compounds proportional to the decline in TEPH.

All of the molecular markers examined during the course of the 64-day study were degraded to some extent. However, the overall rates of degradation of the marker compounds relative to each other did vary. The differences in the concentrations of pristane and phytane on days 33 and 64 of the experiment relative to other measured hydrocarbon components provide qualitative evidence of the microbial degradation of the diesel fuel; however, the changes in marker ratios that were examined could not adequately describe the TEPH that was microbially degraded, and therefore, cannot be used as a quantitative index of petroleum biodegradation. Analysis for other molecular markers, including alkylated and nonalkylated polycyclic aromatic hydrocarbons, is continuing.

In the future, we will expand our studies to examine volatile organic compounds including BETX compound associated with petroleum fuels and chlorinated hydrocarbons. In particular we will focus on the effect of residual petroleum phase on the rate of degradation of volatile chlorinated contaminants. We also plan to utilize the analytical capabilities at the developing Advanced Analytical Center for Environmental Sciences (AACES) to develop new approaches to addressing problems relating to the bioremediation of organic contaminants. These studies include the use atmospheric pressure ionization (API) and laser desorption mass spectrometry (MS).

Recent Publications: Cycling of Coal/Fossil Fuel Contaminants

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Dosskey, M.G. and D.C Adriano. 1993. Trace element toxicity in VA mycorrhizal cucumber grown on weathered coal fly ash. Soil Biology and Biochemistry 25:1547-1552.

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Martin, H.W. More on beautyberry. Palmetto (in press).

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Sandhu, S.S., G.L. Mills, and K.S. Sajwan. 1993. Chapter 8. Leachability of Ni, Cd, Cr. and As from coal ash impoundments of different ages on the Savannah River Site. In Trace Elements in Coal and Coal Combustion Residues, edited by R.F. Keefer and K.S. Sajwan. p. 165-182. Lewis Publishers, Inc. Boca Raton, FL.

Sandhu, S.S. K.S. Sajwan, G.L. Mills, and F.Harrison. 1995. Effects of leachate form coal ash basins of varying age on groundwater quality. pp.383-394. In: Hydrology Days, 14th edition. American Geophysical Union, Atherton, California.

E.2 RADIONUCLIDE CYCLING IN POND B

Radionuclide Cycling in Vertebrates Inhabiting Contaminated Reservoirs

I. L. Brisbin, Jr.

When first initiated, this program focused on the development of an inventory of the radionuclide contaminants in both the abiotic and biotic components of the Pond B Reservoir on the SRS. With the completion of this initial inventory and its publication in *Ecological Monographs*, the emphasis shifted to a more specific focus on the fate and effects of radiocesium (cesium-137) in aquatic biota, particularly those fish and game species which could act as vectors for transfer of this contaminant to the food-chain of the public off of the SRS (e.g. through the off-site movement of migratory waterfowl, etc.)

The approach used in these studies has always been one of not only documenting the actual levels of radiocesium contamination in the various wildlife populations and/or other reservoir ecosystem components, but also of determining the rates and patterns of contaminant uptake by these entities. The nonlinear Richards sigmoid model for example, was developed and defined within this program as a means for predicting the uptake and concentration of radiocesium, as well as non-nuclear contaminants (e.g. mercury), in free-living biota. The predictions of this and other models describing contaminant uptake and concentration are tested through the use of free-living "sentinel" animals which are tamed and released or equipped with radio-transmitters to otherwise make them subject to multiple recapture and whole body contaminant determination and/or biopsy-biomarker sampling. These techniques have, for example, shown the potential utility of cell flow-cytometry techniques as a means of screening for possible genetic damage in free-living wildlife inhabiting contaminated aquatic habitats.

Following the drawdown of the nearby Par Pond reservoir, the focus of this research program was broadened to include studies similar to those described above for components of all of the abandoned reactor cooling reservoirs on the SRS. In particular, this program is now responsible for the radioecological studies and determination of the fate and effects of other non-nuclear contaminants in fish and wildlife populations whose natural history, behavior, and movements are otherwise studied in the program of "Ecological Effects of the Par Pond Drawdown: Wildlife Studies", as undertaken by the SREL Division of Wildlife Ecology and Toxicology. Studies now being undertaken in this regard have included determination of radiocesium and mercury concentration in feral swine, deer, and doves utilizing the exposed Par Pond CERCLA unit mudflat sediments. Until Par Pond was refilled in the winter 1994-1995, this program also studied the uptake, concentration, and effects of radiocesium on free-living "sentinel" bantam chickens established in an enclosure on the Par Pond CERCLA unit; mallard ducks have since replaced the chickens.

Future studies in this area will continue to provide "follow-up" evaluations of radiocesium and other contaminant uptake by waterfowl, fish and other populations in the newly-refilled Par Pond Reservoir, as well as L-Lake. Studies in L-Lake will be emphasized if the decision is made to drawdown this reservoir, thereby exposing its radiocesium-contaminated bottom sediments in a fashion similar to the exposure of Par Pond sediments in 1991. In the future, however, as in the past and present, the same basic principles of experimental design and analysis will be maintained, as indicated above, in order to provide a continuum of information throughout the history of

management of these contaminated reservoir systems on the SRS. Future studies in this area might also soon begin to focus on the semi-aquatic wetland marsh and swamp systems of the Steel Creek Delta below the L-Lake dam. This habitat will almost certainly become a focus for management concern and contaminant transport evaluation if any decision should be made to drain or otherwise alter the water level and flow regime in L-Lake.

Recent Publications: Radionuclide Cycling in Pond B

Brisbin, I.L., Jr. An overview of developments in the concern for global contamination problems in birds: 1990-1994. Journal fur Ornithologie (in press).

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McAlpine, S., O.E. Rhodes, Jr., C.D. McCreedy and I.L. Brisbin, Jr. 1994. Genetic structure in a wintering population of American coots (*Fulica americana*). The Wilson Bulletin 106:738-743.

Peters, E.L. and I.L. Brisbin, Jr. Environmental influences on the ^{137}Cs kinetics of the yellow-bellied turtle (*Trachemys scripta*). Ecology (in press).

Peters, E.L., I.L. Brisbin, Jr. and R.A. Kennamer. Alternative agriculture as an option to environmental remediation: the production of poultry in radiologically contaminated areas. In International Symposium on Environmental Impact of Radioactive Releases. International Atomic Energy Agency (in press).

E.3 SOIL/SEDIMENT REMEDIATION

In situ Remediation Techniques for Contaminated Soils and Sediments

D.C. Adriano, A. Chlopecka, C. Sherony, and J. Weber

This program was created by redirecting funds from the old biobarrier program and, more recently, additional funds were redirected from the cycling of coal/fossil fuel contaminants program. This contamination/remediation program has two basic components: a) radionuclides as the contaminant and b) metals as the contaminant.

A field study was initiated in the fall of 1992 at Par Pond near the SREL boat dock. The exposed lake bed sediment provided the substrate to establish garden plots. This study was precipitated by an earlier dose assessment indicating that ingestion of food products in this area by a hypothetical lake basin inhabitant would represent the greatest exposure risk. Therefore, a study was initiated to evaluate various remedial options on the contaminated sediment to enhance the quality of the food chain by minimizing radionuclide uptake by plants. Several remedial measures were tested; some have been tested widely and some are emerging technologies. The efficacy of the various techniques was measured using crops as indicators. For the fall 1992 crop, collards and cabbages were grown and ^{137}Cs activities determined. Subsequent croppings included kohlrabi, turnips, radish, corn, okra and spinach. These crops were planted over a two year period after adjusting the nutrient requirements for the various treatment plots. Results indicate that providing clean soil cover of about 25 cm thickness over the contaminated sediment resulted in lower cesium uptake than with plants grown where no clean soil cover was provided. The other soil cover treatments (i.e., those with geo-textile fabric and a root biobarrier sandwiched between the clean soil cover and the contaminated sediment) produced even lower cesium uptake than just the plain soil cover. All the treatments involving the soil cover technique produced concentration ratios that were at or below the NCRP guideline value of 0.12. The other techniques tested (i.e., high K fertilizer application and zeolite, clinoptilolite addition), resulted in some diminution of cesium uptake, but they were not as effective as the clean soil cover techniques. Over the project duration, soil cesium decreased with time and with depth, presumably due to the leaching of this element as well as some removal by the crop biomass. This decrease with time coincided with the uptake diminution with time, i.e., uptake was more pronounced in the first year than in the second year. The degree of cesium uptake was influenced by crop species and the plant parts. The deep-rooted collards accumulated more cesium than the other species, and in the case of turnips, kohlrabi, radish, corn and okra, the foliage tissues tended to accumulate more cesium than the edible portions. The results from this study could be extrapolated in terms of remediating severely contaminated soils, such as those affected by the Chernobyl reactor explosion in 1986.

A mimicked *in situ* remediation of metal contaminated soil was started in the spring of 1994. This soil was spiked with metal flue dust from a scrap metal recycling facility. This material was very high in zinc, lead, and cadmium. After incubating the spiked soils, the following soil ameliorants were added: agricultural lime, hydroxyapatite, zeolite, (clinoptilolite), and iron oxide from an industrial waste product called Iron-rich™. Crops (corn, radish, and barley) were used as treatment indicators of the various ameliorants. The use of lime appears to

be as effective as the other materials in terms of mitigating metal uptake, and because lime is fairly abundant and much cheaper than the other materials, it may prove to be the ameliorant of choice. This study now is being expanded, adopting the same approach to investigate additional ameliorants on soils singly contaminated by heavy metals.

Recent Publications: Soil/Sediment Remediation

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).

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E.4 Ecotoxicology and Ecological Risk Assessment Program (EERAP)

Ecotoxicological Research

M.C. Newman

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

Ecotoxicological Research: Bioaccumulation studies of SRS-related pollutants have been completed for two endemic species, the channel catfish (*Ictalurus punctatus*) and largemouth bass (*Micropterus salmoides*). Clearance volume-based pharmacokinetic models for ^{137}Cs, Cd, Hg, Rb and Zn in catfish have been fit and manuscripts are being prepared that describe the results. Results will enhance our efforts to assess accumulation of these metals in an SRS-pertinent species. Similar studies of methylmercury pharmacokinetics in catfish and bass have also been completed and data are presently being fit to candidate models. Tissue blood flow determinations have been initiated to generate essential parameters for pharmacokinetic modeling.

Studied effects included behavioral, genetic and acutely toxic effects. Behavioral studies focused on avoidance of contaminated sediments by mollusks. Genetic studies continued using mosquitofish population response to chronic mercury exposure. Acute toxicity studies used the rapid assessment, microbial assay (Microtox®).

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

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

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

Quantitative Methods: ERA-related quantitative methods were developed during FY95. Version 4.0 of a software package (UNCENSOR) allowing univariate estimation for chemical data sets with "below detection limit" observation was released to 400 registered users. Extensive simulations comparing the incorporated methods have begun. A manuscript describing bootstrap methods of estimating community-level NOEAC has been submitted for publication. The book *Quantitative Methods in Aquatic Ecotoxicology*, by M.C. Newman, described and compared ERA-associated methods.

Education/Training: A short course (*Quantitative Methods in Ecotoxicology*) was taught during FY95 and will be taught annually. A book (*Ecotoxicology: A Hierarchical Treatment*) describing the results of the Second Savannah River Symposium is in press. Plans for a workshop, *Quantitative Risk Assessment*, and negotiations for publication of an associated book continue.

Recent Publications: Ecotoxicology and Ecological Risk Assessment Program (EERAP)

Jagoe, C.H., A.E. Faivre and M.C. Newman. Morphological and morphometric changes in the gills of mosquitofish (*Gambusia holbrooki*) after exposure to mercury (II). Aquatic Toxicology (in press).

McCloskey, J.T. and M.C. Newman. 1995. Asiatic clam (*Corbicula fluminea*) and viviparid snail (*Campeloma decisum*) sediment preference as a sublethal response to low level metal contamination. Archives Environmental Contamination and Toxicology 28:195-202.

McCloskey, J.T., M.C. Newman and P.M. Dixon. 1995. Effect of metal contaminated sediment on the distribution of the asiatic clam, *Corbicula fluminea* populations. Archives Environmental Contamination and Toxicology 28:203-208.

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F. WETLAND SYSTEMS

This research documents the early recovery of wetland floodplain ecosystems from the effects of thermal and other discharges resulting 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

When saline waters enter ecosystems, such as when effluents are released into streams or a hurricane-produced storm surge enters coastal riverine and low-lying terrestrial ecosystems, the impact is dependent on salt content, length of exposure, present abiotic conditions and topography of the ecosystem. For instance, heavy precipitation which usually precedes a hurricane saturates the soils, decreases the hydraulic conductivity of the soil, and lessens the infiltration of saline water. As the storm surge abates, saline water will drain off the higher elevations and reduce their exposure to saline water, but accumulate in depressions, where continued infiltration will occur. Hence, the degree of exposure to the salt stress is affected by both the pre-exposure soil moisture and topographic position.

For this program, the impact of added saline waters on bald cypress growing in both flooded and unsaturated soils was examined. Soils were either freely draining or were flooded for 48 hours before 32 ppt saline water was added. This high salinity water remained for 48 hours, after which natural precipitation and watering, if necessary, slowly diluted and moved the salt into the soils. The freely draining treatment would represent the response of plants on higher topographic positions with high initial infiltration rates, but short exposure to ponded conditions. The response of flooded plants would be similar to that observed from plants growing in depressions; these plants experience minimal initial infiltration of the saline water but salt ultimately infiltrates into the soil. From past studies, it was felt that the treatments would not cause mortality, but that physiological processes would be affected. Therefore, midday photosynthesis and stomatal conductance were determined, as were both predawn and midday xylem pressure potentials.

For plants grown in unsaturated conditions, saltwater moved immediately into the soil and decreased photosynthesis, stomatal conductance and pre-dawn xylem pressure potential within 48 hours. The reductions in photosynthesis and stomatal conductance were due to lower xylem pressure potential for plants in unsaturated and now saline soil. Plants growing in flooded soils showed no initial physiological response to the surge and there was also no initial increase in soil salinity.

By the 19th day post-exposure, saline water had infiltrated into flooded soils. Plants growing in both unsaturated and flooded soils had lower photosynthesis and stomatal conductance. Pre-dawn xylem pressure potential was lower only for plants in flooded soils. The response of the flooded plants was delayed by the slow infiltration rate and potentially was reduced due to the dilution over time.

No mortality was observed due to the treatments and by the following spring, no significant treatment effects in any physiological parameter were observed. When considering hurricane effects, it is curious that the heavy rainfall preceding the saline storm surge may actually afford some protection to the vegetation. These plants will again be subjected to salt stress this summer to study the potential effects of cumulative salt exposure.

Soil saturation which preceded salt addition resulted in reduced plant stress because of a slow salt infiltration rate and a dilution of salt concentration. Without soil saturation, plants responded very rapidly to the salt addition but recovered after the salt passed though the soil. Although the total amount of salt to which the plants were exposed was identical, the maximum concentration and

duration of exposure differed and produced differential responses. Thus, critical factors in predicting the response of vegetation to such a stress must include the maximum concentration and length of time of exposure to the stress, taking into consideration the soil moisture and topographic position.

Fourmile Branch Restoration Demonstration Plot

K.W. McLeod, M.R. Reed and K.T. Barnett

Over the past five years, the Savannah River Technology Center has funded a bottomland forest restoration program for the Fourmile Branch delta. During this time, a great deal has been learned about characteristics of individual species and the best techniques for establishing these species in this highly disturbed delta. This experiment was designed to determine whether using the knowledge gathered from the previous experiments would lead to greater growth, survival and plant community development than planting random species at fixed locations.

Three planting strategies or treatments were used. First, randomly selected species were planted at fixed, uniformly spaced (4 x 4 m) locations. Selection was limited to 5 species (*Carya aquatica, Quercus lyrata, Q. michauxii, Nyssa aquatica,* and *Taxodium distichum*) with 4 saplings of each species used within each plot. This treatment is most similar to that used in operational restoration projects. In the second treatment, species were chosen for planting based on the flood tolerance of the species and the apparent hydrology of the individual fixed planting locations. Finally, in the third treatment both the species and planting locations were chosen by the flood tolerance of the species and the apparent hydrology of the planting locations. Individual planting sites were chosen by the planter and could be no closer than 2 m from any other planting location. This treatment requires the greatest knowledge by the planter of the individual species.

Thus, in each 20 x 24 m plot, 4 individuals of each of 5 different species were planted. Five replicate plots per treatment were selected for the experiment and had a gradient from wet to dry. In this manner, the relative flood tolerance of the 5 species could be exploited. Saplings were also enclosed in Tubex tree shelters to minimize herbivory.

This experiment was installed in the winter of 1995. To date, survival of the individual saplings has been good in all plots. Occasional death of some individuals in the first treatment has occurred where obvious hydrology and flood tolerance did not match. As this year has been relatively dry, the flood tolerances of the species has not been severely tested as it has in some past years. As high water level return to the delta over the autumn and winter, survival of the least flood-tolerant species will begin to be tested.

While the survival of the outplanted saplings is important, it should not the primary indicator of restoration success. The overall development of the biotic community is the real goal of restoration. In addition to documenting sapling survival in these plots, the existence, persistence and growth of the natural recovering vegetation will be documented over time and examined relative to the success of the outplanted saplings.

In the initial survey of the existing vegetation in these plots, 13 different woody species have been identified, with *Fraxinus* sp., *Pinus taeda*, and *Salix nigra* being most abundant. This is an underestimate of the total number of species, since species of some genera could not be separated and some additional species obviously exist in the delta, but were not found in the plots. For instance, neither *Taxodium distichum* and *Nyssa aquatica* were in the plots, yet are becoming established on

portions of the delta.

There is also a strong difference in the success of the woody species associated with relative elevation. The wetter areas are more densely populated, but primarily with *S. nigra*. Tree density per plot ranged from 166 to 1123 stems/ha (mean of 494) for the 15 plots. The role that our outplanted saplings will play in accelerating the succession and the species composition of these plots will be temporally reassessed and contrasted with the natural recovery plots established in the 1987.

Endangered Species

P. M. Dixon

The endangered species component of the ecosystem management program seeks to understand the demography, life history, and management of various rare plants on the Savannah River Site. The primary concern is with *Echinaceae laevigata* (the purple coneflower), a federally endangered species. This species is now known from two sites on the Savannah River Site. In FY94, a newly located site was censused and two subpopulations with a total of 600 plants and 741 stems were found. Continued annual monitoring of this site to document population trends is planned for this year. The population at the Burma Road site continues to decline. Some estimates of population size have been revised in previous years. Plants that were missing at census time have reappeared in subsequent years. In particular, the low population size in 1993, originally reported as 155 plants, has been revised upward to 171 plants. In the summer of 1994, 167 plants were found and 146 plants were found in the summer of 1995.

F.2 LOWER FOOD CHAIN

Potential Effects of Groundwater Contaminant Plumes on the Hyporheic Fauna of SRS

J V. McArthur

Our studies on the hyporheic fauna of the SRS continue to reveal many new organisms and unique distributions. We have completed a seasonal study on the hyporheic fauna located below the stream bed of Meyers Branch Creek. In addition, we are continuing a survey of these organisms below the floodplain of Tinker and Meyers Branch Creeks. To date we have discovered several organisms new to science and have found organisms with very unique distributions. For example, we have discovered an isopod that has previously only been found in southeastern Europe. This suggests that these organisms were separated when the continents split and formed the Atlantic ocean. Additionally, we have discovered a new order and several new species of copepods. These organisms show seasonal and spatial trends. Since contaminated groundwaters do and will continue to come to the surface through seeps located on floodplains and below surface waters, it is critical that we understand the organisms and processes they perform in this difficult-to-observe habitat. These organisms will be the first affected by contamination. Because of their unique distributions and the occurrence of previously unknown organisms it is important that we continue to investigate this habitat to understand what ecosystem processes are controlled by them.

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F.3 ENVIRONMENTAL TRANSPORT PROCESSES

Physicochemical Factors Regulating Facilitated Contaminant Transport

P. M. Bertsch

The reactivity and mobility of contaminants in the environment as well as their bioavailability and toxicity are controlled by chemical speciation and solid phase partitioning. The ongoing research activities within this program are aimed at providing fundamental information regarding the influence of chemical speciation on contaminant reactivity and migration in surface and subsurface environments and on the role of surfaces in regulating contaminant behavior. Additionally, investigations focused on molecular mechanisms of contaminant toxicity are underway to help elucidate the roles of chemical speciation of contaminants in toxicity and of genetically controlled differences in important biological barriers to metal tolerance mechanisms.

The efficacy of specific sorbents for removing contaminants from waste streams or for use in environmental remediation activities is dependent on the nature and distribution of coordination environments within the sorbent having high specificity for the sorbate as compared to other constituents or co-contaminants. We have examined by ^{133}Cs NMR and Cs EXAFS a number of model cation exchange resins and clay minerals that were fully or partially exchanged with Cs. ^{133}CS NMR data from Al-Ca-Cs fractionally loaded sulfonic exchange resin suspensions provided evidence for multiple adsorption sites, comprised of a more populous site (site I) having a preference for higher charged cations, i.e., $Al^{3+} > Ca^{2+} > Cs^{+}$, and a smaller population of sites (site II) having a high preference for Cs. By adjusting the surface coverage of the Al^{3+} and Cs^{+} on the exchanger phase it was possible to isolate the Cs^{+} in a *single* environment. The rotational correlation time (τ_c) for Cs in site II was estimated to be an order-of-magnitude lower than for site I, which was an order-of-magnitude lower than Cs in solution ($1.0x10^{-8}$ s, $7.32x10^{-9}$ s, and $1.5x10^{-11}$ s, respectively), suggesting a highly restricted coordination environment. The quadrupolar coupling constant (χ) of Cs at site II was about twice that of site I (0.226 vs. 0.139 Mhz), suggesting that the Cs existed in a less symmetrical environment at site II, perhaps representing a more highly coordinated site. The Cs EXAFS data were consistent with this interpretation, as Cs adsorbed predominately to the more specifically interacting site (site II) had an average first shell Cs-O distance ~0.021 nm less than the average for the Cs saturated exhanger, where Cs was sorbed to both sites I (85%) and II (~15%). Also, the amplitude of the first shell back-scatterers was greater at *lower* surface coverages indicating a more uniform coordination environment with fewer Cs-O distances. NMR analyses of Cs exchanged and partially exchanged smectite and illite suspensions also revealed multiple adsorption environments on these exchangers and this was further supported by the Cs EXAFS data. Current studies are evaluating the coordination environments of Cs in crown ether complexes that have been proposed as specific sorbents to remove Cs from mixed waste streams or immobilize Cs in environmental remediation activities.

The results of these investigations should aid in the selection and evaluation of new technologies for waste isolation and remediation activities for Cs and Sr contaminated sites. Additionally, these studies provide a framework for extending existing technologies developed for a given site or application to new sites or new applications without repeating expensive and time consuming empirically based efficacy testing.

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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 ECOSYSTEM MANAGEMENT

ECOSYSTEM MANAGEMENT: MEASURING DROUGHT STRESS IN LONGLEAF PINE USING REMOTE SENSING TECHNOLOGIES

J.E. Pinder, III

The most widespread form of ecosystem management on the site is the development of large tracts of land as pine plantations by the USFS Savannah River Forest Station (SRFS). Although this activity was originally initiated to control soil erosion and produce revenue, recent changes in public laws and public attitudes have inspired a greater interest in habitat management and biodiversity. These changes have resulted in the development of plans for large stands of long-rotation longleaf pine on the SRS. A major limitation on the success of these longleaf plantations can be prolonged summer drought. Episodes of prolonged summer drought have occurred in recent years, notably 1990, and more frequent episodes of drought and other forms of extreme weather may be expected due to global warming effects on the southeast. To examine the effects of the 1990 drought on subsequent growth by longleaf pines, a research program has been initiated to correlate space-based measures of drought intensity in the pine canopies with ground-based measures of tree growth. This study will be conducted in cooperation with the SRFS and will provide specific information on the relationship between drought stress and soil type that can be incorporated into planning activities in existing GIS-based management plans.

The basic approach used in this program involves determining the relationship between satellite-based measures of drought stress and the growth rates of longleaf pines. The basic sampling unit comprises an area of forest with 1) a closed-canopy longleaf pine, 2) a similar history of management activities, and a common soil type. These sampling units are based on satellite measures of canopy closure, USFS records of stand management, and 3) SCS soils maps. Satellite-based measures of drought stress are obtained from Landsat Thematic Mapper data (TM) which summarizes the reflectance of solar radiation from the ground surface for 3 visible and 4 infrared bands in 30-m x 30-m areas of ground surface termed pixels. Drought stress may be inferred from the relative reflectance of infrared radiation in TM bands 4 and 5. Where leaves have a low water content, the reflectance in bands 4 and 5 are similar. Where leaves have a high water content, the reflectance in band 5 is much lower than that in band 4. Thus, the ratio of reflectance in band 5 to that in band 4 is a measure of the water content of leaves and may be used as a simple index of drought stress.

Because the ratio of reflectance in bands 5 and 4 is also affected by the canopy architecture (i.e., the density and orientation of leaf surfaces), we have developed a new index that employs multiseasonal acquisitions of TM data to adjust the ratios observed in times of drought for those observed after periods of heavy rain when the moisture content of the canopy is high. We term this index the Relative Moisture Index (RMI), and preliminary comparisons of the RMI versus other drought indices suggest that it is much more sensitive to seasonal changes in moisture content.

To compute the RMI for longleaf stands on the SRS, TM data were obtained for three periods following heavy rains (i.e., November 1989, August 1990, and November 1990). Data were also obtained for three periods of large rainfall deficits (i.e., June 1990, July 1990 and September 1990). The RMI for the June 1990 period are computed using the November 1989 data to serve as a control

for canopy architecture, the July 1990 RMI use the August 1990 data as a control, and the September 1990 RMI use the November 1990 data as a control. The RMI computed in this fashion show pronounced seasonal differences among longleaf pine stands, and these differences among stands will be correlated with tree growth rates by measuring tree ring widths in increment cores obtained from a random sampling of trees within each stand in the winter of 1995-1996. The tree ring widths for each year in the five-year period before 1990 will be compared to those in the years following 1990 to infer reduced growth rates and drought impacts.

This analysis will identify relative drought susceptibility as a function of soil type. Data on tree size at the time of the drought and management activities performed before and after the drought also will be analyzed for their potential effects on drought susceptibility.

Effects of Land Management Practices on Forest Biodiversity

D. W. Imm and K. W. McLeod

During FY95 this biodiversity project concentrated on four research areas: 1) sandhills post-burn recovery, 2) timber compartment manipulation and management, 3) diversity of set-aside slopes, and 4) *Sarracenia minor* habitat and community dynamics. Each project is designed to illustrate how land management practices alter forest diversity.

Post-Burn Recovery in Sandhills Vegetation

This project concerns the effects of fire on community structure, composition, plant species diversity, and ecosystem processes pertaining to resource availability. The research focuses on two sandhills set-aside areas located near Par Pond and B Area. Past research focused on postburn changes and recovery by plant species. These studies have revealed that: 1) fire-induced woody species mortality rates are a function of species characteristics and size, 2) temporal compositional shifts occur following fire and result in highest diversity occurring about 7 years following fire, 3) post-fire plant composition is dependent upon fire season but differences dissipate by the eleventh year due to the loss of fire-adapted herbs and the reestablishment of scrub oaks, 4) post-fire spatial distribution patterns are related to predisturbance conditions and result in temporally enhanced plant resource heterogeneity patterns which, in turn, influence plant species diversity, and 5) plant ground cover associations have differing resource requirements and their presence alters microsite conditions.

Collectively, these results imply that fire is necessary to maintain ecosystem complexity and habitat heterogeneity. The integrated spatial temporal ecosystem dynamics following fire are linked to compositional and size class spatial arrangements. Fire is also necessary to maintain asynchrous ecosystem and successional processing at small scales. For example, we have found summer burns to be more disruptive to preburn compositional patterns than winter burns. Post summer burn compositional recovery to preburn conditions was prolonged and higher plant diversity persisted for a longer period than in the winter burn plots.

To validate the hypothesis concerning spatial and temporal associations following fire, a burn was conducted in the winter of 1992/93 and a summer burn in September 1994; the unburned control area has continued to be monitored and the plots maintained. These second burns will be used to validate mathematical functions that reflect species-specific mortality frequencies relative to size. These frequencies are being used to predict the likelihood of fire-induced mortality in 2-200x20 m mapped species transects. During FY95, the summer burn area and control areas were resurveyed

to allow for comparisons of actual versus predicted results. Changes in vegetative conditions will again be used to assess the effects of fire on plant composition and structure. However, because the preburn conditions between the first and second fires differed, the focus will be to explore the possible positive-feedback relationships between preburn and postburn conditions.

Future direction of this program should focus on continued studies pertaining to spatial and temporal patterns following fire and should be reflective of above and below ground processes that pertain to compositional dynamics, ecosystem processes, and fire behavior. The predominant focus should be on the understory and groundcover layers as opposed to canopy dynamics.

Effects of Management at the Timber Compartment Level

This research is intended to study the long and short term effects of differing management strategies on biodiversity at the timber compartment level. The approach has been to select two adjacent timber compartments (TC32 and TC33) with comparable landform and resource conditions that have slightly different management goals. These timber compartments will be used to compare species diversity within each, relative to management and microsite conditions. These comparisons will be made at the timber stand level as well as timber compartment level.

Sampling efforts during FY95 focused on revisiting permanent plots in both timber compartments to evaluate compositional changes that occurred due to recent management activities. Individual permanent plots also were geographically positioned using GPS equipment with GIS layers pertaining to the vegetative characteristics currently being developed. These GIS layers will be developed collaboratively with the SRFS. The intent of this process is to better define GIS vegetative classification and, thus, aid land management decisions.

Significant findings to date suggest that pine and hardwood systems do not greatly differ in species diversity at small scales (400 m^2); however, they differ at larger scales because of greater landscape heterogeneity and asynchronous age and size class structures. These areas also provide habitat for fire-intolerant species. A second finding is that the interface between set-aside hardwood forests and actively managed pine forests is dominated by weed species and is likely the result of differing management conditions, specifically the exclusion of fire.

Managed pine forests are composed of species less reflective of microsite conditions than are set-aside hardwood (upland and bottomland) areas. This pattern is particularly true under intermediate moisture conditions. This may reflect the presence of spatial and size class homogeneity in planted pine stands and/or altered ecosystem functioning due to the structured nature of planted pine stands.

The lack of correspondence between composition and microsite conditions is less evident in areas that would be considered droughty to excessively well-drained. Naturally established pine stands and those planted have similar compositional attributes and resource pools. The similarity may be reflective of more extreme moisture conditions and/or the presence of fire maintenance.

Currently, ecosystem budgets and transfer pathways are being determined for the various management and microsite conditions. The intention is to better understand the functioning of these natural and anthropogenic ecosystems as well as begin to address issues that pertain to watershed dynamics and cross-boundary interactions between various forest types.

The future direction of the timber compartment project is to assess changes in species diversity conditions relative to the management conditions in place. Preferably these assessments will be made prior to the reevaluation of the prescribed management for individual stands. Timber stands within compartment 33 are scheduled to be represcribed in the year 2000, while compartment 32 is

scheduled to be represcribed in 2002.

Diversity of Set-aside Slopes

Hardwood Slopes and associated corridors provide habitat for species less suited for managed pine forest conditions. As revealed by other studies, these areas are important buffers between pine management areas and wetland systems. During FY95, continued efforts were made to develop an appropriate hardwood classification system that is reflective of soil type, land contour, age, and resource conditions. These areas are suitable for many of the rare species present on site as well as those suitable, but absent, from SRS. Efforts also have been made to consider beta-diversity species turnover rates along topographic gradients and those factors that influence compositional patterns.

During FY95, a study was done to investigate the impact of fire on these oak dominated mixed hardwood systems. These studies focus on a series of plots in an area impacted by an accidental dormant season fire. Post-burn assessment of the fire indicated that fire behavior and burning pattern is strongly influenced by litter type and amount as well as topography. This previously sampled and mapped study area was then resurveyed to determine compositional changes brought about by burning.

Similar to the findings in the sandhill studies, the effects of fire are species and size specific. Following fire, available nutrients increased but dissipated to predisturbance levels within a month of being burned. Relative to pre-burn estimates, oak regeneration was higher following fire and was also higher than that in adjacent unburned areas.

Prior to resampling the vegetation, acorns were collected during the winter months from the burned and adjacent unburned areas and then germinated under greenhouse conditions. The initial hypothesis was that fire would have a negative effect on acorn germination. However, acorn germination rates were higher in those sampled from the burned areas and proportionately favored white oak species.

Future research should focus on: 1) the role of fire in sloped hardwood forests, 2) the relationship between landform and topography to fire behavior and its importance, and 3) the role of the hardwood slope ecosystem in buffering the effects of upland pine management on palustrine forests and wetlands.

Sarracenia minor Habitat and Associated Community Dynamics

During FY95, continued monitoring of the pitcher plant population on the western forest margin of Craigs Pond was conducted. New clumps within the study plots were identified and those outside the study plot boundaries were mapped. For each clump, habitat conditions pertaining to biotic and abiotic features were determined. These characteristics were used to determine optimal habitat conditions and then used to develop a predictive equation to assess whether the species is occupying the seemingly preferred habitat conditions.

In conjuction with the *Sarracenia minor* habitat study, other species within the sample plots also were measured and mapped. Other plots along the ecotonal gradient from upland forest to Craigs Pond also were sampled and mapped and then used to determine the vegetational catena. Therefore, community dynamics along the ecotone can be assessed as well as the specific behavior of the *Sarracenia* population over time. Our data indicate that the population has declined slightly over the past two years. Historically, Carolina bay margins are likely to have been fire maintained,

however, past preventitive fire management has resulted in the invasion of these margins by fire intolerant hardwood species. Thus, the general area is slowly becoming more shady and less favorable to pitcher plant populations and associated cohorts.

Future studies will focus on the impact of fire on the *Sarracenia* population as well as on the vegetational gradient from upland to wetland. Following fire, which is scheduled for winter 1995, the biotic and abiotic components will be resurveyed and assessed. Of particular interest will be whether pitcher plant clumps invade those areas determined to be most suitable following fire.

Microbial Diversity

J V. McArthur

A major objective of these studies is to use molecular tools to compare microbial community structure in relatively pristine streams, with that in streams impacted by SRS operations. Baseline studies on the pristine streams (i.e., Upper Three Runs Creek and Tinker Creek) have been completed this year. These studies have revealed the temporal and spatial patterns of bacterial genetic diversity. and have shown that bacterial populations do have resident and transient forms. An understanding of these patterns is important in managing degraded systems. If a stress or disturbance is great enough, are the resident forms (those adapted to resident conditions) eliminated and if the resident form is lost what ecosystem level changes occur? In addition, we have demonstrated the ability of introduced bacteria to colonize stream habitats. We investigated this process using genetically labeled bacteria. These results suggest that introduced bacteria are successfully able to colonize stream substrates. Clean-up of contaminated sites may involve the introduction of particular microorganisms that are capable of degrading contaminants. It has not definitely been shown that introduced bacteria can effectively compete against resident bacteria and become established to the degree that they can perform the intended process.

We also have collected environmental samples and extracted microbial DNA to construct a DNA library. This library will be used to compare and contrast similar samples collected from degraded streams on the SRS. We have begun DNA sequencing of this library. In addition, we have developed genus and species-specific gene probes for bacteria in the genus *Deinococcus*. These bacteria are the most radiation tolerant organisms on the planet. We will use these probes to determine the effects of chronic exposure of Four Mile Creek bacteria to radiation.

Fire and Sandhills Vegetation

D.W. Imm, K.W. McLeod, and B.S. Collins

Fire has formed the sandhills vegetation. With fire suppression, plant composition is slowly shifting toward oak-dominated forest. Vegetation in unburned and winter-burned sites has been mapped during FY95. Burning decreases the density of mature trees, increases the density of vegetative shoots, and increases the density of grasses and forbs. Overall, the vegetation is less clumped when burned. The sandhills seedbank is sparse, and treatment of seedbank samples by burning or fertilizing did not recruit vegetation from the seedbank. However, grasses common to the sandhills have >50% germination when not water limited. These results suggest that seed density, not germinability, limit regeneration in the sandhills.

Edge Management

B.S. Collins and R.L. Mumme (visiting faculty)

Human activities create edges. On the SRS, given a block size of 30 m, 60% of the landscape is edge. The vegetation, avian activity, and seed predation was studied on 12 recent clearcut edges bounded by young and old forest during spring and summer of 1995. Vegetation of clearcuts is composed primarily of shrubs, grasses, and forbs, with much bare ground. There is, as yet, little difference in species composition on edges compared to interior of clearcuts or forest. In spring, survival of seeds placed on the ground was greatest within 10 m of the edge; decreased to zero at 20 to 40 m into the clearcut and adjacent forest; and increased slightly at 50 m from the edge. Trapping studies suggest that mice species perceive the edge as a barrior, with one species found in the clearcut and another in the forest. Seed predation patterns appear to be the result of lower small mammal density on the edge.

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G.2 FAUNAL DIVERSITY

Herpetofaunal Biodiversity Studies on the SRS

J. W. Gibbons

The Savannah River Site is an ideal environment for the study of herpetofaunal biodiversity due to its varied terrestrial and aquatic habitats, large tracts of protected land, and different management regimes throughout the landscape. In addition, the history of the SRS, along with the availability of human and material resources, have resulted in intensive long-term studies that have generated a large database on the resident herpetofauna. Our long-term goal is to continue to develop and expand this database and to use the information to enhance and/or restore herpetofaunal biological diversity within a managed landscape. The specific objectives of our herpetofaunal biodiversity research program are:

(1) To continue to quantify variations in herpetofaunal population size not due to management regimes (i.e., daily, seasonal, or yearly variation, wetland hydroperiod, and environmental variation due to habitat differences).

(2) To determine the microdistribution of each of the herpetofaunal species occuring on the SRS and how it is related to particular soil types and vegetation communities.

In order to meet these objectives, we have set out coverboard arrays at different types of terrestrial habitats and in the land-water interface of several Carolina bays with varying hydroperiods. These cover boards are maintained throughout the year and some have been censused since the late 1980s. The early data already have been compiled in a book chapter, but future publications are expected and student research projects will continue.

A manuscript has been prepared from a project begun last fall to meet the second objective. It involved using GIS and all existing data on SRS herp captures to map out the distribution of herpetofaunal species on the SRS. Once these microdistributions have been determined, it is possible to compare them to results of soil and vegetation surveys previously conducted by other groups.

These data will suggest mechanisms leading to enhanced or reduced amphibian and reptile biodiversity within managed habitats. Comparative and experimental 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 contraints on land use.

Modeling Population Dynamics of Salamanders in Carolina Bays

P.H. Niewiarowski, J.D. Congdon, P.M. Dixon, R. Pulliam, and B.Taylor

Funded jointly by a grant from the EPA's *Sustainable Biosphere Initiative* (SBI) and SREL's biodiversity program, we have initiated a project which combines: 1) existing demographic and experimental data on growth, survivorship, and reproduction of salamanders in Carolina bays, 2) new, landscape-level experiments estimating habitat effects (clear-cut vs. undisturbed) on growth, survivorship and reproduction of salamanders using terrestrial habitats around Carolina bays, and 3) spatially-explicit, individual-based computer simulation models to predict the population consequences of alternative management scenarios and global climate change. The primary object

of the project is to produce a simulation model that can be used by the USFS to assess impact of alternative management scenarios (e.g., rotation cycles, harvest patterns, harvest and site preparation methods) on Carolina bay salamander populations. A related goal is to develop the specific model into a general approach that could be used for other taxa in different habitats, both on and off the SRS.

A mandate from the SBI project review panel, set up by the EPA, emphasizes that the simulation models be "realistic". Three main components of the mandate for "realism" recognized by the EPA panel are that: 1) models be parameterized from empirical study of the species being modeled, 2) models incorporate factors known to be important to population dynamics, other than habitat manipulation and climate change, and 3) multi-species interactions be included in models. Use of existing data from SREL on salamanders in Carolina bays and landscape experiments described above satisfy the first component. Pursuant to the second and third components, we are conducting additional field experiments through September-October (1995) on the effects of larval competition and predation between the two species of salamanders used in the habitat experiment described above (*Ambystoma opacum* and *A. talpoideum*) in large enclosures at Ginger's Bay.

During the first two years of the project (July, 1993- July, 1995) Biodiversity and SBI funds were used to purchase materials required for simulation modeling (multi-processor pentium and software), begin development of the simulation software, and to hire temporary personnel/students to set up field experiments (32 field enclosures adjacent to the Set-Aside area around Rainbow bay. As of the writing of this report, we have a beta version of the simulation model ready for sensitivity analyses, a manuscript detailing experimental results of clearcutting on metamorph *Ambystoma talpoideum* (one of four experimental groups) that is undergoing in-house review, and we are beginning to collect data on the remaining experimental groups. Preliminary results suggest that habitat changes due to clearcutting may have little or no measurable effect on growth, survival and reproduction. However, prudent interpretation of experimental results will be possible only after recaptures of breeding individuals from the remaining 3 experimental groups is complete in May, 1996. Data analysis and manuscript preparation will follow shortly thereafter.

Biological Diversity and Ecosystem Management of SRS Stream and Carolina Bay Wetlands

G.K. Meffe

This research in this program consists of two areas of pursuit:

Biological Diversity in Beaver Ponds and Streams: The objective of this component is to understand how beaver activities affect biodiversity of SRS streams at local to stream-wide scales. Data are being collected for three taxonomic groups: fishes, aquatic plants, and birds. Species distributions and abundances relative to present and former beaver dams are being determined and associated data on habitat structural changes induced by beaver activities are being collected, as well as conditions in control streams where beavers have not occurred in recent times.

Thirty-one beaver ponds of various sizes, ages, and positions in the landscape have been studied to date with respect to fish diversity; a subset of 15 were used in aquatic plant and bird studies. Additionally, eight former (recovering) ponds were studied, as well as numerous free-flowing

stream segments, for comparative purposes. Electroshocking and seining of all habitats within beaver ponds and free-flowing streams was used to detail the distribution and abundance of fishes in these systems. Concomitantly, extensive habitat measurements were made to describe the pond systems, and Geographic Information Systems (GIS) were used to locate and describe the ponds in a landscape perspective. Significant increases in fish diversity in older, abandoned ponds has been discovered, compared to streams that are uninfluenced by beaver ponds. The age of a pond and its position in the landscape have major influences on fish diversity, and across the SRS landscape a large diversity component is added to aquatic systems by beaver ponds. Also, beaver ponds are very dynamic systems that change over time; no single pond is by itself representative of total landscape influences and many ponds are necessary to maintain fish diversity across the site.

The aquatic plant surveys were completed this year and are being readied for publication. Aquatic plant diversity in beaver ponds was significantly higher than diversity in streams, indicating a critical role for beavers in maintaining plant diversity on the SRS. Again, each pond had some measure of uniqueness, and added to site diversity. Bird studies began in late spring and are still in a preliminary stage.

Fish Species Diversity Patterns Across a Carolina Bay Landscape: Sixty-three Carolina bays were surveyed in summer 1994 and 1995 for presence of fish, using baited minnow traps and hoop nets. Environmental data also were collected, including temperature, pH, redox potential, dissolved oxygen, total dissolved solids, and conductance; landscape parameters such as distance to nearest permanent or intermittent aquatic habitat, elevation of the bay, and elevation of nearest aquatic habitat also were measured. A long-term data set is being developed that will allow analysis of colonization and extinction patterns in these bays, and which will address the importance of these temporary to semi-permanent wetlands to overall biological diversity on the SRS. The first summer's study was recently accepted for publication (Snodgrass et al).

A Large-scale Experimental Approach to Determine the Effects of Coarse Woody Debris on Populations of Insects, Amphibians, Reptiles, Birds, and Small Mammals on the Savannah River Site

J.D. Congdon, J.W. Gibbons, and M. Dorcas

This project is a cooperative study between the Savannah River Forest Station, the University of Georgia, Clemson University, Idaho State University, and the Savannah River Ecology Laboratory to determine the effects of coarse woody debris (CWD) on populations of insects, amphibians, reptiles, birds, and small mammals. The results of this study will be vital when considering the effects of CWD during the development of management plans for forested lands. Coarse woody debris (medium to large size logs left on the ground) may be an important factor in the biology of many organisms. Coarse woody debris may provide important retreat sites with suitable thermal and hydric conditions for many species of insects, amphibians, reptiles, and small mammals. Coarse woody debris also may provide an increased diversity and abundance of invertebrate prey for many amphibians, reptiles, birds, and small mammals. Therefore, consideration of CWD may be vitally important for the proper stewardship of government lands and our efforts to maintain biodiversity.

To provide a template for studies of the effects of CWD, at least four replicated experimental plots (approximately 15-20 acres each) will be established and maintained on the Savannah River Site during the winter of 1995-96. On these plots, CWD will be controlled in specific ways to facilitate integrated research to determine the potential role of CWD as a key resource. Treatments are as

follows:

1. A control in which CWD is not manipulated.
2. Removal, in which all of the woody debris is removed (anything greater than 4 inches in diameter, including standing snags).
3. A control as described in treatment number one that would be available for researchers to introduce large debris of different species and large, old-growth logs for their own detailed studies.
4. A control as described in treatment number one for a baseline period (e.g, 2 years), then extensive felling to simulate a catastrophic wind-fall that would result in a large pulse of CWD.

Sampling of animal populations will be done on the different treatments using standard techniques (e.g., point-count measurements for birds, drift-fencing for amphibians and reptiles). The Savannah River Forest Station, with assistance from the US Forest Service in Athens, will be responsible for establishing and maintaining the experimental treatments. The University of Georgia (D.A. Crossley, Jr.) will conduct the studies on invertebrates, Clemson University will conduct studies of small mammals (Susan Loeb) and birds (Sid Gauthreaux), and Idaho State University/SREL (Charles Peterson/Michael Dorcas) will conduct the studies of amphibians and reptiles.

Activities in 1995 consisted mainly of working with the Savannah River Forest Station and the US Forest Service in Athens to develop a sound experimental design for the treatment template on which the organism specific studies can be conducted.

Recent Publications: Faunal Diversity

Dunning, J.B., R. Borgella, K. Clements, and G.K. Meffe. 1995. Patch isolation, corridor effects, and avian colonization of habitat patches in a managed pine woodland. Conservation Biology 9:542-550.

Feldmann, A.L. 1995. The effects of beaver (*Castor canadensis*) impoundment on plant diversity and community composition in the coastal plain of South Carolina. MS Thesis, University of Georgia, Athens.

Grant, Bruce W., Kent L. Brown, Gary W. Ferguson, and J.W. Gibbons. Changes in Amphibian Biodiversity Associated with 25 Years of Pine Forest Regeneration: Implications for Biodiversity Management, pp. 355-367. In Biological Diversity: Problems and Challenges, edited by S.K. Majumdar et al., Pennsylvania Academy of Science (in press).

Holling, C.S. and G.K. Meffe. On command and control, and the pathology of natural resource management. Conservation Biology (in press).

Meffe, G.K. and S. Viederman. Combining science and policy in conservation biology. Wildlife Society Bulletin (in press).

Seigel, R., T. Lynch and J.W. Gibbons. Population responses by snakes to a major drought. Herpetologica (in press).

Semlitsch, R.D., T.D. Tuberville, and J.W. Gibbons. Timing of reproduction and metamorphosis in the crawfish frog (*Rana areolata*) in South Carolina. Journal of Herpetology (in press).

Sheldon, A.L. and G.K. Meffe. Collective properties and habitat relationships of fish assemblages in coastal plain streams. Canadian Journal of Fisheries and Aquatic Sciences (in press).

Sheldon, A.L. and G.K. Meffe. Short-term recolonization by fishes of experimentally defaunated pools of a coastal plain stream. Copeia (in press).

Snodgrass, J.W., A.L. Bryan, Jr., R.F. Lide, and G.D. Smith. Factors affecting the occurrence and structure of fish assemblages in isolated wetlands of the upper coastal plain, USA. Canadian Journal of Fisheries and Aquatic Sciences (in press).

G.3 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 relatively undisturbed 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 not only will 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) and in meeting the policy objectives of DOE-Environmental Management.

GIS development

The Savannah River Ecology Laboratory (SREL) developed a computer based Geographical Information System (GIS) data layer describing the Set-Aside boundaries, and a working version (Version 4) was generated for image processing simplification and figure attributing in support of the final NERP publication describing the Set-Aside areas. This GIS layer is used on site to ensure that Set-Aside boundary lines are available for consideration by SRS groups making land management decisions. SREL is cooperating with the SRFS to determine the feasibility of using the Global Position System (GPS) to verify the Set-Aside boundaries. Approximately 20 miles of line was GPSed by the SRFS for the purposes of coverage comparisons and area accuracy assessments.

Boundary lines

Periodic inspections of Set-Aside boundary postings were conducted where potential conflicts were anticipated and approximately ten miles of line were refurbished with signs. All SREL Site Use Permits were evaluated to determine whether the permitted research activity was conducted in a Set-Aside as well as for study closure plan implementation to determine whether a potential ecolitter site existed for that Set-Aside. As a result, a second Ecolitter day was held this fiscal year to clean up historical research materials at the UGA Old Lab Site, DOE Set-Aside No. 2. SREL's Site Use Permit database was revamped to include system query capabilities for Set-Aside usage and permit preparation.

Natural Resource management and coordination

SREL's Set-Aside staff continued to participate as an ID team member in the SRFS's natural resource prescription review process for developing management plans for timber compartments. This coordination and planning with the SRFS is successful in verifying Set-Aside and timber stand boundary line coincidence with GIS coverages, in updating sensitive plant population surveys conducted in Set-Aside areas, and in addressing potential conflicts

with forestry activities adjacent to Set-Aside areas prior to initiating Site Use permit coordination. Pre-planning activities for the SRFS's prescribed burning programs continued.

Research and Educational Use

The Set-Aside program solicited proposals for small research projects to be conducted in Set-Aside areas to include floral, faunal, and geochemical-based projects. Five projects were funded this year. They include: a continued study of fish assemblage variation among isolated wetlands (SREL); a biogeographical toad distribution study (SREL); studies of Carolina bay soil characteristics (UNC-Asheville); a study of midstory influences on nesting neotropical migrants in bottomland hardwood forests (SFES/UGA); and, a study of relationships of hydrology and plant regeneration in Carolina bays (SREL).

SREL continued numerous long-term plant and animal studies in Set-Asides and initiated this fiscal year three new studies to include a macroinvertebrate colonization stream study, a rare aquatic perennial plant study, and a study of the reproductive ecology of ground dwelling spiders. Groups other than SREL also continue to use the Set-Aside areas. Research has begun on coarse woody debris decomposition, softmast production in bottomland hardwood forests, and archaeological investigations around Carolina bays. Educational outreach usage of the Set-Aside areas grew significantly this year from both SREL and SRFS's programs. A permanent display case was prepared for UGA's Conference Center to bring public awareness to the Upper Three Runs/Tinker Creek Set-Aside.

Management Plans

Materials were prepared for the Set-Aside Task Group to develop a draft/working Management and Protection Plan for each Set-Aside area. These materials are being evaluated for formulating the desired future conditions of the Set-Asides and for determining what research or management activities are appropriate for Set-Aside areas. A historical records search will be inititated for the documentation of the pre-SRS land use of the Set-Aside areas for the purposes of making recommendations for these plans. In addition, historical prescribed burning practices for each Set-Aside area will be determined for fuel load and burning regimes if necessary.

A NERP document describing the flora, fauna, and biophysical parameters that compose and support each Set-Aside area is in its final draft stages prior to submission to DOE. Reference files are continuously updated for each Set-Aside area to include photos, maps, and all publications and research efforts associated with each Set-Aside.

Future accomplishments for the Set-Aside program will focus on finalizing the NERP document on Set-Aside areas, working in cooperation with the SCDNR Heritage Trust program and the SC Nature Conservancy to developing a management plan for each Set-Aside area, continued utilization of the Set-Asides for educational outreach purposes, and evaluating other SRS GIS coverages that include Set-Aside boundaries. Continuing to establish permanent plots for gathering baseline data for those Set-Asides where survey data are lacking will be a priority. The sensitive plant survey being conducted by the SRFS will continue to be updated and incorporated into the Set-Aside GIS coverage. Continued research within Set-Aside areas will provide valuable baseline information that will aid DOE in the operation, restoration, and remediation of SRS site facilities.

Recent Publications: DOE Set-Asides [publications and data sets that used Set-Asides]

Aho, J.M., J V. McArthur, R.B. Rader, and R.W. Wolfe. Leaf litter processing in a southeastern blackwater stream: roles of season and leaf quality. Archiv Fur Hydrobiologie (in press).

Boileau, M.G. and B.E. Taylor. 1994. Chance events, habitat age, and the genetic structure of pond populations. Archiv fur Hydrobiologie 132:191-202.

Brooks, M.J., B.E. Taylor, and D.J. Colquhoun. 1994. Holocene climate and upland landscape evolution in the Upper Coastal Plain of South Carolina. Annual Review of Cultural Resource Investigations by the SRARP - Fiscal Year 1994. pp. 29-33.

Davis, C.E. and D.J. Karapatakis. 1995. GIS dataset of Set-Aside boundary lines - file SETASIDE (Version 4). SREL Metadata for GIS. Savannah River Ecology Laboratory, Aiken, S.C.

Buhlmann, K., T.K. Lynch, J.L. Greene, and J.W. Gibbons. Prolonged egg retention in the chicken turtle, *Deirochelys reticularia*. Herpetologica (in press).

Burke, V.J. and J.W. Gibbons. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina bay. Conservation Biology (in press).

Burke, V.J., J.L. Greene, and J.W. Gibbons. The effect of sample size and study duration on metapopulation estimates for slider turtles. Herpetologica (in press).

Frazer, N.B. Herps and NERPS: Herpetological research at a National Environmental Research Park. Herpetologica (in press).

Gibbons, J.W. Measuring declines and natural variation in turtle populations: spatial lessons from long-term studies. In Proceedings from An International Conference on Conservation, Management, and Restoration of Tortoises and Turtles (in press).

Gibbons, J.W. and D.R. Jackson. *Deirochelys reticularia* (Latreille, in Sonnini and Latreille, 1801) Chicken turtle. In Conservation Biology of Freshwater Turtles (in press).

Gibbons, J.W. 1994. Reproductive patterns of reptiles and amphibians: considerations for captive breeding and conservation. In Captive Management and Conservation of Amphibians and Reptiles, A Volume Honoring Roger Conant, edited by J.B. Murphy, K. Adler, and J.T. Collins. p. 119-123. Vol. Contributions to Herpetology, Vol. II. Society for the Study of Amphibians and Reptiles. Ithaca, NY.

Hartman, G.D. 1994. Seasonal effects on sex ratios in moles collected by trapping. The American Midland Naturalist 133:298-303.

Jenssen, T.A., J.D. Congdon, R.U. Fischer, R. Estes, D. Kling, S. Edmands, and H. Berna. Behavioural, thermal, and metabolic characteristics of a wintering lizard (*Anolis carolinensis*) from South Carolina. Functional Ecology (in press).

Jones, R.H., D.S. Segal, and R.R. Sharitz. 1994. Cation dynamics in bottomland hardwood forest litter. The American Midland Naturalist 131:248-256.

Jones, R.H., R.R. Sharitz, S.M. James, and P.M. Dixon. 1994. Tree population dynamics in seven South

Carolina mixed-species forests. Bulletin of the Torrey Botanical Club 121:360-368.

Leff, L.G. Stream bacterial ecology: a neglected field? ASM News (in press).

Leff, L.G., R.M. Kernan, J V. McArthur, and L.J. Shimkets. 1995. Identification of aquatic *Burkholderia (Pseudomonas) cepacia* by hybridization with species-specific rRNA gene probes. Applied and Environmental Microbiology 61:1634-1636.

Leff, L.G., J.R. Dana, J V. McArthur, and L.J. Shimkets. 1995. Comparison of methods of DNA extraction from stream sediments. Applied and Environmental Microbiology 61:1141-1143.

Lide, R.F. 1994. GIS dataset of SRS Bays - file (Version 3). SREL Metadata for GIS. Savannah River Ecology Laboratory, Aiken, S.C..

Lide, R.F., V.G. Meentemeyer, J.E. Pinder III, and L.M. Beatty. 1995. Hydrology of a Carolina bay located on the upper coastal plain of western South Carolina. Wetlands 15:47-57.

Meffe, G.K., S.C. Weeks, M. Mulvey, and K.L. Kandl. Genetic differences in thermal tolerance of mosquitofish from ambient and thermally elevated ponds. Canadian Journal of Fisheries and Aquatic Sciences (in press).

Mills, G.L., C.P. Wolfe, and J V. McArthur. Lipid composition of suspended particulate organic matter (SPOM) in a southeastern blackwater stream. Water Research (in press).

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Plummer, M.V. and J.D. Congdon. Rates of metabolism and water flux in free-ranging racers, *Coluber constrictor*. Copeia (in press).

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Rader, R.B. and J V. McArthur. 1995. The relative importance of refugia in determining the drift and habitat selection of predaceous stoneflies in a sandy-bottomed stream. Oecologia 103:1-9.

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Communities, edited by Martin L. Cody and Jeffrey Smallwood. Academic Press, Inc. (in press).

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Snodgrass, J.W., A.L. Bryan Jr., R.F. Lide, and G.M. Smith. Factors affecting the occurrence and structure of fish assemblages in isolated wetlands of the Upper Coastal Plain, USA. Canadian Journal of Fisheries and Aquatic Sciences (in press).

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Vaikus, M. R. and K. W. McLeod. 1995. Photosynthesis and water-use efficiency of two sandhill oaks following additions of water and nutrients. Bulletin of the Torrey Botanical Club 122:30-39.

Wagele, J.W., N.J. Voelz, and J V. McArthur. Older than the Atlantic Ocean discovery of a freshwater Microcerberus (Isopoda) in North America and erection of Coxicerberus n. gen. The Journal of Crustacean Biology (in press).

Wein, G.R., and E. LeMaster. 1995. Ecosystem management on the U.S. Department of Energy's Savannah River Site. Poster presentation at NEPA25, sponsored by USDOE, Washington, D.C. March 20-22, 1995.

Whiteman, H.H., T.M. Mills, D.E. Scott, and J.W. Gibbons. Confirmation of range extension in the pine woods snake, *Rhadinaea flavilata*. Herpetological Review (in press).

Wise, M.G., L.J. Shimkets, and J V. McArthur. 1995. Genetic structure of a lotic population of *Burkholderia* (Psuedomonas) *cepacia*. Applied and Environmental Microbiology 61:1791-1798.

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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 genetic material. 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.

H. ENVIRONMENTAL TOXICOLOGY

Genotoxicology Studies

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

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

Our studies of contamination by mercury and cesium-137 of largemouth bass in lakes on the Savannah River Site indicate that both mercury and cesium are active in causing breaks in DNA strands. In the absence of mercury, strand breaks are repaired very rapidly; however, when mercury is present, it appears that mercury inhibits the rate of repair of DNA breaks and thus, breaks persist for longer periods of time. Therefore, the worst condition for largemouth bass is to be in environments that contain both cesium and mercury because under these conditions cesium exacerbates the rate of strand breakage and mercury serves to impede the repair of these breaks.

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

Perhaps the most surprising results were obtained from rodents living adjacent to reactor number 4 in Ukraine. These small mammals are experiencing alarming rates of mutation in the cytochrome b gene of their mitochondria. Rates of mutations are at least 40 times higher than those seen outside of the contaminated zone. Not only is the rate of mutation higher but also the placement of the mutations is very unusual when compared to other mammalian taxa. There were almost equal substitution rates for first position, second position and third position nucleotides in the triplet codons. Mutations also were obvious in the fetuses from a single mother. These results show that the mutations are still ongoing in the region around Chernobyl reactor number 4. It is important now to determine the costs of such mutations to the lifespan and productivity of the affected organisms.

Analyses of soil samples collected at Chernobyl in 1992 and 1993 have been completed and two manuscripts have been submitted based on the samples collected in 1992. Other manuscripts are in preparation reporting levels of contamination in soils and in the muscle tissue of animals surrounding Chernobyl's reactor. Little radioactive contamination was found in regions to the south and east of the power plant in 1992, although lead levels in many of the fish

sampled in this region were high. In contrast, fish samples collected from the north and northwest of the plant in 1993 had elevated radiocesium concentrations but were relatively low in mercury and lead.

Current research in the ecotoxicology program includes assessment of genetic damage for the protein produced by the p53 gene. We also are sequencing the p53 gene in rodents from the Chernobyl region. The p53 gene is a proported tumor suppressor in humans and it is likely that it has a similar function in other organisms. When the DNA of a cell is damaged, the p53 gene is activated producing a protein that blocks cell division until the DNA damage is repaired. Thus, this gene prevents the proliferation of cells with damaged DNA which may lead to cancer. Thus the amount of this protein in the cells of an organism provides a sensitive measure to any recent exposure to genotoxic agents. We also are very interested in any mutations to this p53 gene that may render its activity insufficient for tumor suppression.

Recent Publications: Environmental Toxicology

Dallas, C. E., C. H. Jagoe, S. K. Fisher, K. A. Holloman, R. K. Chesser, M. H. Smith and M. Lomakin. Evaluation of genotoxicology in wild organisms due to the Chernobyl nuclear disaster. In Animal World and Ecosystems in Conditions of Radioactive Pollution. Nauka Science Publishers. Russian Academy of Sciences, Moscow (in press).

Fisher, S. K., C. E. Dallas, C. H. Jagoe, M. H. Smith, I. L. Brisbin, Jr. and R. K. Chesser. 1994. Sources of error associated with sample collection and preparation of nucleated blood cells for flow cytometric analysis. Cell Biology and Toxicology 10:145-153.

Fisher, S. K., J. T. Lingenfelser, C. H. Jagoe and C. E. Dallas. 1995. Evaluation of the effects of cryopreservation of isolated erythrocytes and leukocytes of largemouth bass (*Micropterus salmoides*) by flow cytometry. Journal of Fish Biology 46:432-441.

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.

I. 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.

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

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

During the past year, SREL scheduled more than 300 lectures, 52 tours and 15 exhibits. One exhibit, the Southeastern Wildlife Expo in Charleston, S.C., was attended by an estimated 60,000 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 200 media affiliates and officials of DOE and the University of Georgia. The program also has promoted various research projects through coverage in local and national media and has worked to enhance the laboratory's internal communications. Included among these have been coverage of SREL research by CNN, U.S. News and World Report, Associated Press, BioScience, Earth Magazine, National Wildlife Magazine, and National Public Radio. This program also has been responsible for planning and organizing special events, including tours for dignitaries and several reptile and amphibian identification workshops for the general public. Ongoing projects include two internal laboratory newsletters, one published on a monthly basis, the other weekly, and an increased number of video projects. A 27-minute six-projector automated slide presentation about SREL research was completed last year and it has become a regular part of SREL tours. Another innovative educational product completed this year was

a full-color poster that describes the life history of several species of freshwater turtles. A teacher's guide accompanies the poster, which has been distributed to elementary schools in Georgia and South Carolina. This poster has received high praise from educators across the region.

The division also has 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 18 other states. The undergraduate students were funded by grants from the National Science Foundation (NSF) and DOE.

Also this summer, SREL participated in a program for pre-college teachers sponsored by Associated Western Universities. Five 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 senior ecologist Dr. Whit Gibbons, also could receive five hours of graduate credit from Mercer University 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. Subsequent repair of the dam and refill of Par Pond was completed early in 1995. On-going studies are examining the effects of the refill.

J.1 ECOLOGICAL EFFECTS OF THE PAR POND DRAWDOWN: WILDLIFE STUDIES

Wildlife Studies

I. L. Brisbin Jr.

This program is designed to compliment the contaminant fate and effects studies being conducted by the program "Radionuclide Cycling in Vertebrates Inhabiting Contaminated Reservoirs", being conducted in the SREL Division of Biogeochemistry. In particular, this program studies the general ecology, basic natural history, movement and behavior of those wildlife species which are of special concern - particularly with regard to their potential to act as off-site vectors of contaminant transport to the food chain of the hunting public. Studies have been particularly focused, for example, on waterfowl (in coordination with the program of "Waterfowl Research on the SRS"), and on doves, which were found to feed on the exposed contaminated sediments of the Par Pond CERCLA unit following the drawdown of that reservoir in 1991.

Data are collected from opportunistic observations of wildlife which are obtained in conjunction with the conduct of other studies at the Par Pond CERCLA unit. In addition, selected individual animals (particularly alligators) have been equipped with radiotransmitters and their movements have then been monitored throughout the period of reservoir drawdown and subsequent refill. Systematic boat cruises are made around the perimeters of Par Pond, L-Lake and Pond B to census and evaluate spatial and temporal changes in the avifaunal community structure and diversity of these aquatic systems. A particular effort is made to coordinate this work with studies of the wood stork and bald eagle, as they may be found to forage on the Par Pond CERCLA unit habitats. These studies serve as a "ground truth" for aerial surveys for storks, waterfowl, and eagles conducted by the SREL programs of "Waterfowl Research on the SRS" and "Wood Stork Research Program".

In another component of this program, wood duck nest boxes have been erected around the periphery of Par Pond, and their use by ducks and other cavity-nesting wildlife species is checked at regular intervals during breeding seasons. During this past year, a brood of screech owls occupying one of these nest boxes was found to exhibit limb abnormalities. Three nestlings exhibited limb deformities which ranged from having one extra digit on the limb to having two extra completely formed legs. Two other nestings appeared normal, as did the putative male parent of the brood; the putative female parent had an extra digit on one limb. Although the abnormal owlets did not survive, the putative parents and the two unaffected owlets were taken into captivity and have since been placed in an owl breeding program managed by the U.S. Fish and Wildlife Service. It is hoped that a collaborative study by USFWS and SREL will provide information on the heritability and genetic basis for this condition in screech owls.

Future studies in this area will also continue to document the movement and behavior of alligators and other wildlife populations which may continue to use the Par Pond site following reservoir refill. Most of these programs either will be greatly reduced or phased-out completely after a year of baseline data have been collected following the refill. Studies of the aquatic wading bird community and other avifauna for example, will be terminated after a full

annual cycle has been documented following refill. An additional year of reduced effort still will be needed, however, to complete the development of spatially-explicit GIS models to document and analyze the movement and behavior of various wildlife components of the Par Pond ecosystem. A particular effort will be made to use this GIS-based approach to integrate the data obtained in this program with complimentary contaminant concentration and movement data obtained in other SREL research program efforts as described above.

Recent Publications: Par Pond Drawdown: Wildlife Studies

Brisbin, I.L., Jr. Genetic studies of economically important traits of domestic animals: the importance of conserving the wild ancestors. Conservation Biology (in press).

Brisbin, I.L., Jr., J.M. Benner, L.A. Brandt, R.A. Kennamer, and T.M. Murphy. 1992. Long-term population studies of American alligators inhabiting a reservoir: initial responses to water level drawdown. p. 53-76. In Crocodiles - Proceedings of the 11th Working Meeting of the Crocodile Specialist Group of the SSC of the IUCN - The World Conservation Union, IUCN. Victoria Falls, Zimbabwe.

IMPROVED QUANTITATIVE TECHNIQUES

Bryan, A.L., Jr., T.M. Murphy, K.L. Bildstein, I.L. Brisbin, Jr. and J.J. Mayer. Use of reservoirs and other artificial impoundments by bald eagles in South Carolina. In Raptor Adaptations to Human Influenced Environments, edited by D.M. Bird, D.E. Varland, a nd J.J. Negro. Academic Press. London (in press).

Fisher, S.K., C.E. Dallas, C.H. Jagoe, M.H. Smith, I.L. Brisbin, Jr. and R.K. Chesser. 1994. Sources of error associated with sample collection and preparation of nucleated blood cells for flow cytometric analysis. Cell Biology and Toxicology 10:145-153.

Mayer, J.J. and I.L. Brisbin, Jr. Feral swine and their role in the conservation of global livestock genetic diversity. In Proceedings of the 3rd Global Conference of Domestic Animal Genetic Resources (in press).

McAlpine, S., O.E. Rhodes, Jr., C.D. McCreedy and I.L. Brisbin, Jr. 1994. Genetic structure in a wintering population of American coots (*Fulica americana*). The Wilson Bulletin 106:738-743.

Peters, E.L., I.L. Brisbin, Jr. and R.A. Kennamer. Alternative agriculture as an option to environmental remediation: the production of poultry in radiologically contaminated areas. In International Symposium on Environmental Impact of Radioactive Releases. International Atomic Energy Agency (in press).

Staton, M.A., H.M. Edwards, Jr., I.L. Brisbin, Jr., T. Joanen and L. McNease. 1992. The influence of environmental temperature and dietary factors on utilization of dietary energy and protein in purified diets by alligators, *Alligator mississippiensis* (Daudin). Aquaculture 107:369-381.

J.2 ECOLOGICAL EFFECTS OF THE PAR POND DRAWDOWN: FISH AND METAL STUDIES

Effects of the Par Pond Drawdown and Refill on Littoral Zone Fishes

G. K. Meffe

The littoral region of Par Pond is the interface between the terrestrial habitats and the open water pelagic zone. The shallow nature of the littoral zone allows light penetration to the bottom, often resulting in dense growths of primary producing plants. The plants transfer nutrients into organic material that moves up the food chain. Consequently, the littoral zones are often the most productive areas and play an important role in the overall productivity of a lake. Additionally, the littoral zone is used as a spawning and nursery area for juvenile fishes. Smaller juvenile fish, as well as other smaller species of fish, find refuge from larger open water predators in the littoral zone.

The draining and subsequent refilling of the Par Pond system completely disrupted the critical littoral zone as well as energy flows throughout the system. The refilling of Pond C and Par Pond, and subsequent submersion of terrestrial plants, is supplying a large pulse of energy into the system. As the pulse diminishes, re-establishment of the littoral zone will be paramount to full recovery. Fish communities will respond to and reflect these changes as the littoral zone develops and eventually stabilizes.

Changes in the littoral zones of Pond C will be reflected in the fish communities present. This Fall, examinations will begin on fish community structure and fish abundance in the littoral zone of Pond C and will document the natural recovery process. Approximately six regular sampling locations will be established along the shoreline of Pond C and quarterly collections of fishes will be made. These collections will be restricted to the shallow littoral zone, and will involve multiple passes with small-mesh bag seines of eight to 30-foot lengths. All larger fish will be identified, measured, and released at the sites; smaller individuals will be identified and counted in the field, or, if too small, will be preserved and analyzed in the lab. Our data will then be incorporated with that of Dr. Justin Congdon into an Index of Biotic Integrity (IBI) for the system. Development of such an index will both provide a target for recovery and indicate where in the recovery process the system exists at any given time.

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

J.D. Congdon and R.D. Nagle

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. Prior to 1994, fish were collected by electroshocking during four distinct periods, 1) reactor operation, 2) reactor shutdown, 3) six months after draw down, and 4) one year or more after draw down. A total of seventeen species of fish were caught, and data were collected on 4,851 fish during the four collection periods. 2,038 fish were individually marked with permanent tags. 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. During 1994 we added 1,050 and 1875 captures of fish to the Par Pond and Pond C data bases. In Par Pond 17 species, and in Pond C 15 species of fish were captured. In Par Pond the numerically dominant species were bluegill (27%) and bass (19%), whereas in Pond C bass, bluegill, and lake chubs represented 26%, 18%, and 18% of the fish sampled, respectively. Some of the new dominant species entering the pond during the past three sampling periods were yellow perch, black crappie, redbreast sunfish, warmouth, and lake chub sucker, which are more typical of fish assemblages in normothermic ponds. We will continue systematic collections of Pond C and Par Pond to monitor the dynamics of the fish community.

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

J.D. Congdon, R.D. Nagle, 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 their body condition by determining whole body lipids. We have collected and marked 1,536 fish (18 species) from Par Pond and 2,268 from Pond C (17 species). A total of 314 recaptures of marked fish have been made in both ponds, 232 in Pond C and 82 in Par Pond. The two most dominant species in both ponds are bass and bluegill, which comprise 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 for Par Pond and at 12 for Pond C. However, during the long reactor down period, we observed a variety of species in both sites disappearing, with new species taking their place, indicating a community not at equilibrium. We will continue systematically to 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 Cycling and Accumulation

C.H. Jagoe

Trace metals, especially mercury, are pollutants of concern on SRS. Catchable size bass and other fish in waters including Par Pond, Pond B and L Lake contain sufficient mercury in the edible portion of their muscle to present a health threat if consumed regularly, according to federal guidelines. This research was initiated to study the potential effects of the Par Pond drawdown and refill on mercury cycling in Par Pond, especially impacts on mercury levels in gamefish. This work also considers mercury accumulation in other biota, and mercury dynamics in other waters for comparative purposes.

Current theories hold that mercury bioavailability is controlled by methylation rate and

water chemistry. Methylation is the process by which inorganic mercury is converted to an organic form that is then taken up into organisms from water and food. Methylation is related to bacterial activity in sediments, and may be influenced by pH and concentrations of dissolved organic matter. The drawdown of Par Pond altered the water chemistry of the basin and increased sediment resuspension. During the drawdown period, terrestrial vegetation became established on the exposed mudflats. When Par was refilled, this vegetation was submerged and began to decay. This process should increase both bacterial activity and the release of dissolved organic matter, which in turn may increase mercury bioavailability.

Samples of largemouth bass have been collected at quarterly intervals from Par Pond since December 1991, except for a period in 1992 when access to Par Pond was restricted. Water samples were collected at semi-monthly intervals, and samples of other biota from the pond, including forage fish, plants, benthic invertebrates and alligators were collected at irregular intervals. From fall 1991 through the end of 1994, mercury content of largemouth bass from Par Pond ranged from 0.5 to 2 mg Hg/kg wet mass. Mercury content did not differ among sampling locations within Par Pond, but was strongly related to fish size, with larger fish having higher mercury concentrations. Most catchable size bass exceeded 0.5 mg Hg/kg wet mass, which has been established as a consumption advisory level.

Bass condition factor initially increased after the drawdown, due to the increased availability of prey displaced from shallow, weedy areas by the lowered water level. As the prey populations declined due to excessive predation, food resources for bass probably became scarce. Condition factor began to decline, and continued to decline during the drawdown. Forage species varied considerably in mercury content, with the highest levels (mean 0.13 mg/kg wet mass) found in brook silversides. About six months after the drawdown, there appeared to be a transient increase in muscle mercury concentration in bass, possibly related to changes in diet. However, through the drawdown period until refill was begun, there was no significant overall trend in bass mercury content.

Par Pond was refilled in late winter 1995. Bass collections have continued through the summer of 1995, and analyses of these samples are underway or pending. As longer-lived, larger animals feeding at higher trophic levels, bass tend to average out short-term fluctuations in mercury availability. To detect shorter term effects, we collected samples of several small, shorter lived fish species before and after the refill. These smaller fish contain much less mercury, making accurate quantification difficult with older methods. We are presently using cold-vapor atomic fluorescence (CVAF) as a technique accurately to measure mercury at lower concentrations. Initial QA/QC tests indicate that this method yield results identical to those from analysis techniques we previously used, with much lower detection limits.

Because mercury bioaccumulates, levels in long lived, top-level predators can become quite high. Alligators represent such predators in Par Pond and other SRS waters. Samples from about 50 Par Pond alligators showed elevated mercury levels; averages of 17 mg Hg/kg dry mass liver, and 2.2 ppm in blood. For comparison, alligators were sampled from a area of the Florida Everglades known to be highly contaminated with mercury, and they were found to contain much more mercury than Par alligators. A manuscript on this work is in preparation. The attempt is being made to develop a correlation between mercury levels in muscle and internal organs and readily sampled tissues such as blood and scutes. This would allow non-lethal, repeated sampling of individuals, and would be useful for biomonitoring.

Mercury and other trace metals in fish in other SRS waters are also an area of interest. Over 150 yellow bullheads from Pond B were analyzed for muscle Hg and ^{137}Cs, and a

subsample of these for Cd, Cu, Pb and Zn. Radiocesium body burdens reached an asymptote in 3-year-old-fish, and did not increase further with fish age. In contrast, mercury concentrations continued to increase with age, and fish age was a much better predictor of mercury content than was fish size. Three year old bullheads from Pond B contained about 4500 bq ^{137}Cs/kg wet mass, and about 0.5 mg Hg/kg wet mass. Concentrations of the other trace metals were very low and not related to size or age. A manuscript detailing these findings is in preparation.

Most work on fish mercury emphasizes fish as a dietary item for man or other animals, rather than considering the potential effects of mercury on the fish themselves. However, dissolved mercury in water interferes with ion and osmoregulation and causes gill damage. A manuscript on the changes in gill tissue structure caused by mercury exposure in the laboratory is currently in press. A related study, on the relationship between tissue mercury levels and gill ATPase enzymes, has been submitted. For the latter study, bass were sampled from Par Pond and L-Lake on the SRS, and from Thurmond Lake. All bass were similarly sized, but the fish from SRS waters had higher liver and muscle mercury concentrations. L Lake fish tended to have more mercury than Par Pond fish, but the difference was not statistically significant.

Sampling of bass and other biota from Par Pond will continue through 1995, to detect refill related effects. Various management scenarios for Par envision stabilized water levels at various pool heights, or allowing the level to fluctuate. Deciding among these options will require consideration of the potential effects on trace metal bioavailability and cycling. Also, management decisions involving other SRS waters will benefit from the data developed in these studies.

Recent Publication: Par Pond Drawdown: Fish and Metal Studies

Haines, T.A., Komov, V.T., and C.H. Jagoe. 1994. Mercury concentration in perch (*Perca fluviatilis*) as influenced by lacustrine physical and chemical factors in two regions of Russia. In: C. Watras and J. Huckabee, Eds. Mercury Pollution, Integration and Synthesis. Lewis Publishers, Boca Raton, FL. pp. 397-407.

Jagoe, C.H., Faivre, A. and M.C. Newman. Morphological and morphometric changes in the gills of mosquitofish (*Gambusia holbrooki*) after exposure to mercury (II). Aquatic Toxicology (in press).

Meffe, G.K., S.C. Weeks, M. Mulvey, and K. L. Kandl. Genetic differences in thermal tolerance of mosquitofish from ambient and thermal ponds. Canadian Journal of Fisheries and Aquatic Sciences (in press).

Mulvey, M.E., G.P. Keller, and G.K. Meffe. 1994. Single- and multiple-locus genotypes and life history responses of *Gambusia holbrooki* reared under two temperatures. Evolution 48:1810-1819.

K. IMPROVED QUANTITATIVE TECHNIQUES

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.

K. IMPROVED QUANTITATIVE TECHNIQUES

Improved Quantitative Techniques

P.M. Dixon

This research program develops better statistical methods to analyze environmental and ecological data. Chance variation is a component of every measured environmental quantity. Statistical analysis seeks to extract accurate conclusions from imprecise data and to quantify the uncertainty in those conclusions. Better statistical methods provide two benefits for environmental restoration and remediation: 1) more accurate conclusions from limited data and 2) less data needs to be collected to reach sufficiently accurate conclusions. Our work has concentrated on three projects: the analysis of toxicant accumulation curves, the assessment of spatial pattems, and the analysis of shape.

One major problem in the analysis of toxicant accumulation curves is that the most reliable data are collected by exposing animals (for example ducks on Par Pond) and repeatedly sampling the body burden of some contaminant (for example Cs concentration). Each observation contains two sources of variation: variation among ducks in feeding behavior and metabolism, and variation among replicate Cs measurements. Previous statistical analyses have ignored one or the other of these sources of variation. We have developed a nonlinear mixed model that includes both components of variation. The model gives more precise predictions of cesium concentrations than do earlier models.

Spatial patterns have many consequences in population biology and ecology. For example, trees damaged by high winds may be randomly located or concentrated into clusters, creating large gaps. These two spatial patterns have different consequences for understory growth and forest succession. We have developed a new statistical technique to test whether damaged trees are clustered, forming gaps, or are randomly located. The technique is based on the distances between damaged trees, compared to the distances from damaged trees to undamaged trees. The efficiency of the technique depends on the underlying spatial pattern of trees. For spatial patterns, the new technique is 2.5 times more efficient than alternatives. This means either that smaller differences in spatial pattern can be detected, or that smaller sample sizes can be used. The new technique also has been used to evaluate spatial clustering of leukemia cases and can be applied to other examples of epidemiology.

We have been interested in the potential use of shape as a measure of stress. Previous observations suggested that there are observable shape differences in individuals exposed to stress. To quantify and assess the variation in these potential indicators of stress, we have developed statistical analyses of shape. These have been used with two organisms: dandelions exposed to cadmium stress and mosquitofish exposed to food stress. The statistical analysis suggests that the differences due to stress are smaller than the variation among individuals. Hence, the aspects of shape that can be quantified will be poor measures of organism stress.

L. DOE-SR NATIONAL ENVIRONMENTAL RESEARCH PARK

The Savannah River Site was the first of seven National Environmental Research Parks created and maintained on DOE reservations throughout the United States. The SRS research park was dedicated in 1972 with the purposes of promoting environmental research, conservation and protection of natural resources.

L. DOE-SR NATIONAL ENVIRONMENTAL RESEARCH PARK

National Environmental Research Park Program

N.B. Frazer

A National Environmental Research Park (NERP) is an outdoor laboratory for ecological research, study of the environmental impacts of human activities, and informing the public of landuse options open to them. Because access to DOE land is limited, environmental research projects can be carried out with a minimum of interference. The NERP is not simply a site to conduct research, but should have programs planned to address these general objectives: (1) develop methods to quantitatively and continually assess and monitor the environmental impact of human activities, (2) develop methods to estimate or predict the environmental response to proposed or ongoing activities, and (3) demonstrate the impact of various activities on the environment and evaluate methods to minimize adverse impacts. Pursuant to these objectives, it is necessary to supply basic data so that environmental decisions, standards, and monitoring programs can be developed upon a firm ecological base.

Previously, NERP initiatives changed annually as directed from DOE-OHER in Washington, but the final disposition of the NERP program has fallen to local DOE officials because it is no longer supported by DOE's Office of Energy Research. This past year, proposals were sought and reviewed by a committee composed of three of SREL's scientists (one from each research division) and the NERP Director. Eleven proposals were recieved; three were funded:

1. Response of Mobile Animals to Landscape Pattern in Managed Habitats. This study represents a cooperative effort involving SREL, the University of Georgia Institute of Ecology, and the USFS Savannah River Forest Station. It examines the role of nectar plant distributions on butterfly movements and monitors the distribution of egg and larval forms of *Papilio trolius* in response to differing landscape management tactics. The study is intended to assess the effects of spatial heterogeneity on animal distributions, under a range of scenarios resulting from active management or natural disturbances.

2. Determination of Avian, Insect, and Herpetofaunal Biodiversity in Wetlands and Managed Forests by Use of Continual Monitoring and Audio-Survey Equipment. This is a comparative study of wetland and upland terrestrial sites on the SRS to develop an auditory monitoring system designed to establish daily and seasonal activity patterns of vocal insects, amphibians, and birds. The technique to be perfected is a Portable Automated Recording System (PARS) for automatic recording of animal vocalizations at unattended field sites. A long-term goal is to use the technique to address questions related to biodiversity, populations abundance, life history, and ecological characteristics of selected species of animals. This study also represents a cooperative effort involving SREL and the USFS Savannah River Forest Station.

3. Cytosolic Accumulation of Al in Living Plant Cells. The primary objective of this investigation is to provide the first direct measurement of cytosolic Al accumulation in plant cells and to validate more conventional approaches to studying Al uptake in plants by utilizing a very rare isotope of Al

(^{26}Al) and a new technology for its detection, accelerator mass spectrometry (AMS). Phytotoxicity of Al as a result of soil acidity is a major problem for agriculture and forestry and presents major challenges with respect to revegetation of disturbed lands. Understanding of the physiological basis of Al toxicity and resistance continues to be limited by a lack of reliable information concerning the dynamics of Al movement across the plasma membrane of plant cells. Initial experiments have demonstrated the validity of the protocol developed and have provided the first unambiguous data regarding the cytosolic accumulation of Al in living cells. Experiments in progress will investigate the role of complexing ligands on the accumulation process and the intracellular compartmentation (cell wall, cytoplasm, vacuole) of Al in single cells.

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

A. NOTEWORTHY EVENTS AND SPECIAL ACTIVITIES

- Following several years of planning, opening ceremonies were held in February for the 5,000 ft^2 multi-purpose conference center that was funded by the University of Georgia Research Foundation. The center is located on 68 acres of land that was provided by the Department of Energy.

- The 6,000 ft^2 office and library addition to SREL's main building officially opened this year, and construction plans are underway on a new animal care facility, laboratory addition, and receiving building.

- The management team was restructured to include representatives from the technical and support staff.

- Dr. Nat Frazer served on the Planning Committee for the Southeastern Science and Technology Colloquium held at the Kennedy Space Center in June 1995.

- Dr. Whit Gibbons co-hosted a Workshop on the Ecology and Conservation of Diamondback Terrapins at Savannah River Ecology Laboratory in August.

- Drs. Ronald Chesser, Michael Smith and Derrick Sugg traveled twice to the Chernobyl nuclear site in Ukraine this past year, continuing their research on the genetic effects of radiation and other contaminants on animal populations.

- Last Fall, Dr. Domy Adriano taught a metals course at the Institute of Soil Science, University of Agriculture and Forest Resources in Vienna, Austria.

- In April, Dr. Rebecca Sharitz taught a graduate course titled, "Current topics in plant ecology and evolution" in Sweden. This course was sponsored by the Swedish government and was organized by Umeå University.

- Also in April, the Savannah River Ecology Laboratory hosted a panel discussion titled, "Environmental stewardship and religion: conflict or partnership?" Representatives from local area religious organizations took part in this discussion with members of the SREL faculty. This event was held at the new Conference Center.

- Dr. Michael Newman was invited to teach a short course in April titled, "Statistical methods and software for toxicological data analysis" at the Society for Environmental Toxicology and Chemistry annual meeting in Surrey, England. He also taught a week-long course on

quantitative methods in ecotoxicology at the SREL conference center in July for professionals and graduate students.

- Drs. Domy Adriano and Paul Bertsch participated in the Third International Conference on the Biogeochemistry of Trace Elements in Paris France in May 1995.

- An outside peer review of research programs was conducted for the Division of Wetlands Ecology.

- Internal performance reviews were completed for the head of the Division of Wetlands Ecology and for the head of the Division of Biogeochemical Ecology.

- An initial evaluation of current research programs was completed to assess relevance to the changing Department of Energy/Savannah River Site mission.

B. AWARDS, HONORS, AND OUTSTANDING RECOGNITION

Dr. Domy Adriano was elected president of the Subcommission on Soil Remediation of the International Soil Science Society. He currently chairs a steering committee seeking to establish an International Soil Remediation Center.

Research Technician **Tracy Bertram** was awarded the Best Map Composition Award at the Earth Resources Data Analysis System Users Group Meeting for her poster titled "Deforestation and forest fragmentation in the Upper Coastal Plain of Georgia and South Carolina".

Dr. Paul Bertsch was promoted to senior research scientist and full professor of Agronomy with tenure by the University of Georgia.

Almost two million dollars was obtained through the efforts of **Dr. Paul Bertsch** for the establishment of an Advanced Analytical Center for Environmental Sciences (AACES). Plans are underway to construct a modern laboratory and user facility for the innovative application of advanced instrumentation to address environmental concerns.

Dr. Paul Bertsch was elected vice-chair of the board of governors of the Consortium for Advanced Radiation Sources at the University of Chicago. This consortium will raise funding for beam line construction and coordinate earth and environmental science teams using the advanced photon source being constructed by the Department of Energy at Argonne National Laboratory.

Graduate student **Vincent Burke** was awarded Best Student Paper for his presentation "Terrestrial buffer zones and wetlands conservation: a case study of freshwater turtles in a Carolina bay" at the 9th annual meetings of the Society for Conservation Biology in Fort Collins, Colorado.

Dr. Sue Clark was appointed to a National Academy of Sciences committee on the Waste Isolation Pilot Plant.

Dr. Justin Congdon was honored with a distinguished alumni award by the California Junior College System.

A paper written by **Dr. Justin Congdon**, and co-authored by Arthur E. Dunham and R.C. van Loben Sels, has been selected for inclusion in the new textbook series titled, *Readings in Conservation Biology.* The paper, titled "Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms", has been chosen for both the first volume *To Preserve Biodiversity -- An Overview,* and the second volume, *Genes, Populations, and Species* of the new series.

Dr. Nat Frazer's paper, titled "Sea turtle conservation and halfway technology", also has been selected for inclusion in the first volume of the *Readings in Conservation Biology* series titled, *To Preserve Biodiversity -- An Overview.*

Another SREL paper, written by **Dr. Gary Meffe,** has been chosen for the *Readings in Conservation Biology* series. "Techno-arrogance and halfway technologies: salmon hatcheries on the Pacific Coast of North America", has been selected for the second volume titled, *Genes, Populations, and Species.*

Adrienne Edwards received the Outstanding Teaching Assistant Award from the University of Georgia for her duties in the Botany Department. She also received a University of Georgia Academic Enrichment Award of $1,300 for Excellence in Teaching and Research.

Dr. J. Whitfield Gibbons was honored with a prestigious teaching award at the annual meeting of the Association of Southeastern Biologists in Knoxville, TN.

Karen Kandl received the Braun Award for best student poster from the Ecological Society of America in Knoxville, TN. Her poster was titled, "Inbreeding, family and genotype affect environmental tolerance of mosquitofish".

Dr. Joseph Pechmann received an award for Best Student Oral Presentation at the 1994 Henri Siebert Student Paper Competition for his paper titled, "Population regulation in complex life cycles: aquatic and terrestrial density-dependence in the narrow-mouthed toad". The event was held at the University of Georgia and was sponsored by the Herpetologists' League and the Society for the Study of Reptiles and Amphibians.

Dr. Rebecca Sharitz is continuing a second year as Secretary General for the International Congress of Ecology.

Dr. Rebecca Sharitz was appointed to a National Research Council committee examining non-economic and economic values of biodiversity.

Dr. Michael H. Smith was recognized as a fellow of the American Association for the Advancement of Science, in Atlanta, GA, for his work in population biology and for administration of the Savannah River Ecology Laboratory's interdisciplinary environmental research and education program.

Dr. F. Ward Whicker was presented with the 1994 Distinguished Service Award by the Health Physics Society Radiation Section.

The **Division of Environmental Outreach and Education** received an Award of Excellence in the category of Institutional Relations Projects from the Council for the Advancement and Support of Education in the Central Savannah River Area.

Kathryn Gubista, a graduate student, received the American Society of Mammalogists (ASM) Award for her paper entitled "Litter size of *Peromyscus leucopus*: effects of food limitation", and was invited to present her paper at the plenary session of the ASM annual meeting in June at the University of Vermont.

Several Savannah River Ecology Laboratory researchers were recognized at the Central Savannah River Area Chapter of Sigma XI awards ceremony:

Technician **Russ Bodie** received the first place undergraduate award for his paper titled, "A comparison of diel nest temperature and nest site selection for two sympatric species of freshwater turtles".

Dr. Tom Risch received the first place graduate award for his paper titled, "Is mean litter size the most productive? A test in Columbian ground squirrels".

Dr. John Krenz and Technician **David Scott** received the second place graduate award for their paper titled "Terrestrial trial courtship affects mating locations in *Ambystoma opacum*".

David Hernandez, a graduate student, received the third place graduate award for his paper titled, "Mosquitofish populations in the Altamaha and Ogeechee drainages of Georgia: Reporting an undescribed form in the Ocmulgee River".

Evelyn Gaiser, a graduate student, received the third place graduate award for her paper titled, "Seasonality, substrate preference and attachment sites of epizoic diatoms on cladoceran zooplankton".

III. PUBLICATIONS AND PRESENTATIONS

A. Journal Articles and Book Chapters Published

SREL
Reprint No.

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1881 Martin, H.W. and W.C. Liebhardt. 1994. Tomato response to long-term potassium and lime application on a sandy ultisol high in nonexchangeable potassium. Journal of Plant Nutrition 17:1751-1768.

1882 Gibbons, J.W. 1994. Management of the desert tortoise and other reptiles and amphibians: Time for an environmental attitude adjustment. p. 169-173. In Desert Tortoise Council Proceedings of 1987-1991 Symposia, Las Vegas, NV.

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Chesser, R. K. **Invited.** Chernobyl: Seven Years After. University of Memphis. Memphis, TN. November 1994

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Chesser, R. K. **Invited.** Effective Population Size. Texas Tech University. Lubbock, TX. November 1994.

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DeBiase,A.E.and B.E.Taylor. **Poster.** Biodiversity and Biography of Southeastern Coastal Plain microcrustaceans. American Society of Limnology & Oceanography. Reno, NV. June 1995.

Dixon, P.M. Examining segregation in multivariate point processes. International Environmentrics Society. Burlington, Ontario. August 1994.

Dixon, P. M. **Invited.** Using nearest-neighbor designs and analyses in ecological experiments. Ecological Society of America. Knoxville, TN. August 1994.

Dixon, P.M. Ecological modelling at Savannah River Ecology Laboratory. North Carolina State University Biomathematics Faculty Research Symposium. Raleigh, NC. February 1995.

Dixon, P.M. Segregation in bivariate spatial point processes. Biometrics Society. Birmingham, AL. March 1995.

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Dixon, P.M., Analyzing community data. American Society of Limnology and Oceanography. Reno, NV. June 1995.

Dosskey, M. and P.M. Bertsch. Dynamics of dissolved organic carbon transport through forest soils on the southeastern Coastal Plain. Soil Science Society of America. Seattle, WA. November 1994.

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Foré, S.A. and S.I. Guttman. The spatial scale of genetic differentiation of *Helianthus occidertialis* and *Asclepia verticillate* in a preserve with fragmented habitat. Society for Conservation Biology. Fort Collins, CO. June 1995.

Foré, S.A. and S.I. Guttman. **Poster.** Genetic structure of *Helianthus occidentalis* in a preserve with fragmented habitat. Ecological Society of America. Knoxville, TN. August 1994.

Frazer, N.B. and J V. McArthur. Upper three runs creek: a threatened national treasure. Society for Conservation Biology. Ft. Collins, CO. June 1995.

Gaines, K. and W.L. Stephens. **Poster.** Habitat use during winter dormancy of Eastern box turtles (*Terrapene*

carolina carolina) in a suburban ecotone. Portland, OR. July 1995.

Gall, E., L.I. Snyder, A.L. Bryce, and S.B. Clark. The competitive effects of Ca(II) on Eu(III) sorption to goethite. American Chemical Society. Anaheim, CA. April 1995.

Garrett, K.A. and P.M. Dixon. **Poster.** Evaluation of statistical techniques for measuring temporal change in community composition. Ecological Society of America. Knoxville, TN. August 1994.

Garrett, K.A. **Invited.** Spatial models of plant competition: Environmental heterogeneity, higher order interactions, and agricultural applications. Oregon State University. April 1995.

Garrett, K.A. Higher order interactions among spatially mapped individuals: an iterative approach. Society for the Study of Evolution. Montreal, Canada. July 1995.

Garrett, K.A. and P.M. Dixon. Environmental pseudointeraction: the effects of ignoring the scale of environmental heterogeneity. Ecological Society of America. Snowbird, UT. July 1995.

Gibbons, J. W. **Invited.** Reptiles and Amphibians. Audubon Naturalist Society. Washington, DC. October 1994.

Gibbons, J.W. **Invited.** The benign and maligned: reassessing reptiles in the environmental age. Audubon Naturalist Society lecture series. Washington, DC. October 1994.

Gibbons, J.W. **Invited.** Biodiversity of reptiles and amphibians in North America. University of Georgia. Athens, GA. November 1994.

Gibbons, J.W. **Invited.** The benign and maligned: reassessing reptiles in the environmental age. Central Florida Herpetological Society. Orlando, FL. December 1994.

Gibbons, J.W. **Invited.** Biodiversity in the central Savannah River area. Sunrise Rotary Houndslake. Aiken, SC. December 1994.

Gibbons, J.W. **Poster.** Parental investment in reptiles. 2nd World Congress of Herpetology. Adelaide, Australia. January 1995.

Grant, J.L., M.J. Brooks, and B.E. Taylor. Evolution of Carolina bays on the Savannah River Site, South Carolina: new constraints from ground penetrating radar. American Geophysical Union. Baltimore, MD. May 1995.

Gubista, K. Litter size of *Peromyscus leucopus*: effects of food limitation. American Society of Mammalogists. Burlington, VT. June 1995.

Gubista, K. Ecological, genetic and life history variation: comparison of two *Peromyscus* species. Appalachian Biogeography Symposium. Blacksburg, VA. June 1995.

Gubista, K. *Peromyscus* population decline: causes and consequences. Mountain Lake Biological Station. Blacksburg, VA. June 1995.

Hernandez, J.D. Heterosis and outbreeding depression in mesocosm populations founded with mosquitofish from two locations separated by various distance. Society for Conservation Biology. Fort Collins, CO. June 1995.

Held, M.E. and D.W. Imm. Post-fire seedlilng survival and establishment within ericaceous patches and sandhill habitats. Botanical Society of America. Knoxville, TN. August 1994.

Hickox, T. and B.S. Collins. Natural regeneration on microsites in an oldgrowth bottomland hardwood forest. Botanical Society of America. Knoxville, TN. August 1994.

Hinton, T.G., Y. Ivanvo, N. Arkhipov, and A. Arkhipov. **Invited.** Foliar absorption studies at Chernobyl. European Community Radioecology Program, Paul Scherrer Institute. Mol, Belgium. October 1994.

Hinton, T.G. Uptake of Cs by plants compared to operationally-defined availability from sequential extraction results. National Institute of Standards and Technology. Gaithersburg, MD. June 1995.

Holloman, K., C.E. Dallas, S.K. Fisher, C.H. Jagoe, R.K. Chesser, and M.H. Smith. **Poster.** Patterns of aneuploidy and other abnormalities in blood cell DNA in fish from contaminated regions of Ukraine. American Association for the Advancement of Science. Atlanta, GA. February 1995.

Holloman, K., S.K. Fisher, J. Kind, W. Christmus, R. Wentworth, C.E. Dallas, R.K. Chesser and M.H. Smith. **Poster.** Variation in blood cell DNA content in fish from Chernobyl-contaminated regions in Ukraine and Belarus. Southeastern Regional Meeting of the Society of Toxicology. Knoxville, TN. October 1994.

Hudson, R.J., G.L. Mills, and B.E. Herbert. **Poster.** Weathered diesel oil as a sorptive phase for hydrophobic organic compounds in aquifer materials. Geological Society of America. Seattle, WA. October 1994.

Hudson, R.J., G.L. Mills, and B.E. Herbert. **Poster.** Sorption of hydrophobic organic compounds to residual diesel oil in aquifer materials. American Chemical Society. Anaheim, CA. April 1995.

Hunter, D.B., S.B. Clark, P.M. Bertsch, and S. Bajt. Uptake and metabolism of metals by aquatic plants determined by synchrotron x-ray absorption microanalysis. Soil Science Society of America. Seattle, WA. November 1994.

Hunter, D.B. **Invited.** Application examples of the hard x-ray microprobe at X26A to relevant environmental problems. National Synchrotron Light Source Seminar Series. Upton, NY. October 1994.

Hunter, D.B., S.B. Clark, P.M. Bertsch, and S. Bajt. Synchrotron x-ray microanalysis of Se and Cr in environmental samples. American Society of Agronomy, CSSA-Soil Science Society of America annual meetings. Seattle, WA. November 1994.

Hunter, D.B. **Invited.** Development of state-of-the-art analytical methods for investigating complex environmental problems. University of Alberta. Edmonton, Canada. March 1995.

Imm, D.W. Local and regional patterns of compositional change within forested plant communities. American Institute of Biological Sciences. Knoxville, TN. August 1994.

Imm, D.W. Potential global warming affects at the local scale. University of South Carolina. Aiken, SC. November 1994.

Imm, D.W. and K. McLeod. Interactive relationships between vegetation, disturbance and time at small to intermediate scales. International Association of Vegetation Scientists. Houston, TX. June 1995.

Jagoe, C.H., R.K. Chesser, C.E. Dallas, M.H. Smith, and M.D. Lomakin. **Poster.** Contaminant distribution in ponds near Chernobyl: Patterns of Aneuploidy and other abnormalities in blood cell DNA in fish from contaminated regions of Ukraine. American Association for the Advancement of Science. Atlanta, GA. February 1995.

Jagoe, R.H. and M.C. Newman. **Poster.** Bioaccumulation models with time lags: Dynamics and stability criteria. Society of Environmental Toxicology and Chemistry. Denver, CO. November 1994.

Kandl, K.L. Demographic and genetic consequences of chronic environmental stress on eastern mosquitofish populations. Ecological Society of America. Snowbird, UT. July 1995.

Kemner, K.M., W.T. Elam, D.B. Hunter, and P.M. Bertsch. EXAFS studies of CsBr-dibenzo-18-rown-6 ether solutions. 8th International Conference on EXAFS Spectroscopy. Berlin, Germany. August 1994.

Kennett, R. **Invited.** Freshwater turtle ecology in the wet-dry tropics of northern Australia. Gainesville, FL. November 1994.

Koetsier, P. and J V. McArthur. **Poster.** Comparison of invertebrate assembly patterns in blackwater stream, river and floodplain habitats. North American Benthological Society. Keystone, CO. June 1995.

Leeper, D. **Poster.** Biomass and production of benthos in an isolated wetland. American Society of Limnology and Oceanography. Reno, NV. June 1995.

Lindell, A., P. Koetsier, and J V. McArthur. **Poster.** Do artificial samplers mimic natural substrate in southeastern blackwater streams? North American Benthological Society. Keystone Resort, CO. June 1995.

Liu, H.-P. and J. B. Mitton. Paternal mitochondrial DNA differentiation far exceeds maternal mitochondrial DNA and allozyme differentiation in the freshwater mussel, *Anodonta grandis grandis*. Society of Systematic Biologists. Montreal, Quebec. July 1995.

McArthur, J V. and L.K. Shimkets. Spatial patterns in aquatic bacterial genetic diversity: testing the information spiraling concept. International Association for Ecology. Manchester, England. August 1994.

McArthur, J V. and L.J. Shimkets. Living together for 3.8 billion years: a prime in microbial community ecology. North American Benthological Society. Keystone, CO. June 1995.

McArthur, J V. **Invited.** Physiological and genetic determinants of lotic bacterial distribution and abundance. International Limnological Society. São Paulo, Brazil. July 1995.

McCarron, J.K., W. Conner, and K.W. McLeod. Inundation and salinity stress of a wetland woody species, buttonbush. Association of Southeastern Biologists. Knoxville, TN. April 1995.

McCarron, J.K. and K.W. McLeod. Inundation and salinity stress on bald cypress (*Taxodium distichum*). Ecological Society of America. Snowbird, UT. July 1995.

McCloskey, J.T. and M.C. Newman. **Poster.** Predicting metal effects and interactions on light output in bacteria (*Photobacterium phosphoreum*) using coordination chemistry data. Society of Environmental Toxicology and Chemistry. Denver, CO. November 1994.

McCreedy, C.D., R.A. Kennamer, and I.L. Brisbin. Radiocesium in mourning doves using a contaminated lakebed exposed by drawdown. Annual Midwest Fish and Wildlife Conference. Indianapolis, IN. December 1994.

McCreedy, C.D., J.P. Robinson, L.T. Glickman, H. HogenEsch, I.L. Brisbin, and C.H. Jagoe. **Poster.** Characterization of catfish immune cells by cell flow cytometry: An application in environmental toxicology. Annual Midwest Fish and Wildlife Conference. Indianapolis, IN. December 1994.

McLeod, K.W., M.R. Reed, V.H. Parrish, and T.G. Ciravolo. Bottomland restoration in the Southeastern Coastal Plain. U.S. Army Corps of Engineers. New Orleans, LA. April 1995.

McLeod, K.W., J.K. McCarron, and W.H. Conner. Effects of inundationa and salinity on three woody coastal species. Association of Southeastern Biologists. Knoxville, TN. April 1995.

McLeod, K.W. Effects of inundation and salinity on three woody coastal species. Association of Southeastern Biologists. Knoxville, TN. April 1995.

Meffe, G. K. and S. Viederman. **Invited.** Combining science and policy in conservation biology. The Wildlife Society. Albuquerque, NM. September 1994.

Meffe, G. K. **Invited.** Natural heritage programs, paradigm shifts, and conservation policy. The Nature Conservancy. Columbiana, AL. November 1994.

Meffe, G.K. **Invited.** The challenge of a land ethic. U.S. Fish and Wildlife Service. Arlington, VA. November 1994.

Meffe, G. K. **Invited.** Sustainable development: conservation panacea or politically covert ecocide? Society for Conservation Biology. Edmonton, Alberta Canada. June 1995.

Meffe, G.K. and C.S. Holling. The pathology of natural resource management. Society for Conservation Biology. Fort Collins, CO. June 1995.

Miller, S.P. Variation in foliar nutrient content of two wetland plants along a wetland gradient. Society of Wetland Scientists. Boston, MA. June 1995.

Mills, G.L. Membership chairman's report to Executive Committee, Division of Environmental Chemistry. American Chemical Society. Washington, DC. August 1994.

Mills, G.L., R. Hudson, and B. Herbert. **Poster.** Weathered diesel oil as a sorptive phase for hydrophobic organic compounds in aquifer materials. Geological Society of America. Seattle, WA. October 1994.

Mills, G.L. Career opportunities in environmental chemistry. Claflin College. Orangeburg, SC. October 1994.

Mills, G.L. **Invited.** Transport and remediation studies of diesel oil contaminants in terrestrial systems. Battelle Pacific Northwest Laboratory. Richland, WA. November 1994.

Mills, G.L., G. Voos, J. O'Neill, and W.A. Jones. **Poster.** Organic molecular markers for estimating the biodegradation of petroleum hydrocarbons in soil. Soil Science Society of America. Seattle, WA. November 1994.

Mills, G.L. **Invited.** Bioremediation and transport of diesel contaminants in terrestrial environments. University of Tulsa. Tulsa, OK. March 1995.

Mills, G.L., G. Voos, J. O'Neill, and W.A. Jones. **Poster.** Organic molecular markers for estimating the biodegradation of petroleum hydrocarbons in soil. American Chemical Society. Anaheim, CA. April 1995.

Moyer, B.P., D.W. Imm, and M.R. Reed. **Poster.** Spatial distribution patterns of *Sarracenia minor* adjacent to a Carolina bay. American Institute of Biological Sciences. Knoxville, TN. August 1994.

Newman, M.C. Statistical methods and software for toxicological data analysis. Society of Environmental Toxicology and Chemistry. Denver, CO. October 1994.

Newman, M.C. Enhancing toxicity data interpretation with survival time analysis. Society of Environmental Toxicology and Chemistry. London, England. April 1995.

O'Neill, J., G. Voos, G.L. Mills, L. Johnson, and W. Jones. **Poster.** Organic molecular markers for estimating the biodegradation of petroleum hydrocarbons in soil. Soil Science Society of America. Seattle, WA. November 1994.

Pauley, E.F., S.C. Nodvin, T.B. Coffey, A.K. Rose and N.S. Nicholas. Vegetation, biomas, and nitrogen pools in a Great Smoky Mountain watershed. Ecological Society of America. Knoxville, TN. August 1994.

Pauley, E.F., B.P. Allen, B.M. Dietsch, and R.R. Sharitz. Post-hurricane changes in floodplain forest of the Congaree Swamp National Monument in South Carolina. Association of Southeastern Biologists. Knoxville, TN. April 1995.

Pechmann, J.H.K. Population regulation in complex life cycles: aquatic and terrestrial density - dependence in the narrow-mouthed toad, *Gastrophyrene carolinensis.* Ecological Society of America. Knoxville, TN. August 1994.

Peters, E.L.. **Poster.** Environmental effects on energy metabolism and ^{86}Rb elimination rates of goldfish (*Carassius auratus*). Society of Environmental Toxicology and Chemistry. Denver, CO. October 1994.

Peters, E.L. Invited. Environmental influences on the ^{137}Cs kinetics of the yellow-bellied slider turtle (*Trachemys*

scripta). Tulane University. New Orleans, LA. October 1994.

Peters, E.L. **Invited.** Introduction to radioecology. Morris College. Sumter, SC. November 1994.

Peters, E.L. **Invited.** Influences of ecological processes on the kinetics of radioactive materials. Colorado State University. Fort Collins, CO. November 1994.

Phillippi, T.E. and P.M. Dixon. Initial steps toward a method of analyzing vegetation samples including temporal change. International Association for Vegetation Science. Houston, TX. June 1995.

Pinder, J.E., III. Forest invasion of a volcanic mudflow in Northern California. Savannah River Ecology Laboratory. Aiken, SC. December 1994.

Plague, G.R. and J V. McArthur. Genetic variability in the Endemic caddisfly, *Cheumatopsyche richardsoni* (Trichoptera: Hydropsychidae). North American Benthological Society. Keystone, CO. June 1995.

Reed, M.R., K.T. Barnett, and K.W. McLeod. Is competition control necessary for bottomland restoration? U.S. Army Engineer Waterways Experiment Station. New Orleans, LA. April 1995.

Reed, M.R., V.H. Parrish, T.G. Ciravolo, and K.W. McLeod. **Poster.** Experiences in restoration of a thermally degraded bottomland forest. Association of Southeastern Biologists. Knoxville, TN. April 1995.

Rhodes, 0. E., Jr., B.H. Miller, M.H. Smith, and J.R. Sweeney. **Poster.** Relationships between gonadal reserves and multilocus heterozygosity in male white-tailed deer. Moredun Research Institute. Edinburgh, Scotland. August 1994.

Risch, T., S. Dobson, and J. Morie. Offspring productivity from litters of Columbian ground squirrels: is the mean litter size the most productive? American Society of Mammalogists. Burlington, VT. June 1995.

Safter, W.J. The Savannah River Ecology Laboratory comprehensive health and safety committee. National Safety Council Congress and the Department of Energy Occupational Safety and Health Conference. San Diego, CA. October 1994.

Schultz, I.R. and W.L. Hayton. Comparison of trifluralin toxicokinetics between hatchery rainbow trout and steelhead. Society of Environmental Toxicology and Chemistry. Denver, CO. November 1994.

Schultz, I.R., W.L. Hayton, and B.K. Kemmenoe. Toxicokinetics and disposition of diquat in rainbow trout and bluegill sunfish. Society of Environmental Toxicology and Chemistry. Denver, CO. November 1994.

Schulze, D.G. and P.M. Bertsch. Overview of synchrotron based techniques in soil and environmental sciences. Soil Science Society of America. Seattle, WA. November 1994.

Seaman, J.C., P.M. Bertsch, W.P. Miller, and D.E. Radcliffe. **Poster.** Ionic tracer movement through the highly weathered soils and sediments of the Upper Coastal Plain. Soil Science Society of America. Seattle, WA. November 1994.

Seaman, J.C. and P.M. Bertsch. Solute transport through highly weathered soil and alluvial sediments of the

Upper Coastal Plain. American Geophyisical Union. San Francisco, CA. December 1994.

Seaman, J.C., P.M. Bertsch, and D. Kaplan. **Invited.** Surface chemical controls on colloid generation and mobility in surface and subsurface environments. International Conference for the Advancement of Geochemistry. State College, PA. May 1995.

Sharitz, R.R. **Invited.** Effects of altered hydrologic conditions on small scale environmental heterogeneity and regeneration of bottomland hardwood forests. Ecological Society of America. Knoxville, TN. August 1994.

Sharitz, R.R. Woody plant regeneration in southeastern floodplain forest. International Congress of Ecology. Manchester, England. August, 1994.

Sharitz, R.R. **Invited.** How do wetlands benefit society? Edisto Basin Project Issue Forum. Orangeburg, SC. September 1994.

Sharitz, R.R. **Invited.** Woody species regeneration in southeastern floodplain forest. Duke University. Raleigh/Durham, NC. November 1994.

Sharitz, R.R. **Invited.** Wetlands laws and restoration. Earth Matters: News Coverage of the Environment. Aiken, SC. March 1995.

Sharitz, R.R. **Invited.** Plant dispersal and establishment, with examples from temperate forests. Umeå University. Sweden. April 1995.

Sharitz, R.R. **Invited.** Diversity and regeneration of woody species in forests of the southeastern USA. Umeå University. Sweden. April 1995.

Sharitz, R.R. **Invited.** The balancing act: two scientists in the same family. Umeå University. Sweden. April 1995.

Sharitz, R.R. **Invited.** Natural recruitment in floodplain forests of the southeastern USA. Uppsala University. Sweden. May 1995.

Sharitz, R.R., E. Pauley, and B. Allen. **Poster.** Spatial pattern of disturbance and recovery from hurricane winds in an old-growth floodplain forest. International Association of Vegetation Science. Houston,TX. June 1995.

Sharitz, R.R. and W.D. Marshall. **Invited.** Classification as a framework for environmental management. International Association of Vegetation Science. Houston, TX. June 1995.

Sharitz, R.R., E.F. Pauley, B.P. Allen and M.B. Dietsch. Canopy-understory relationships in a disturbed old-growth floodplain forest. Ecological Society of America. Snowbird, UT. July 1995.

Smith, M.H. Population ecology and genetics of a white-tailed deer herd. Third International Congress on the Biology of Deer. Edinburgh, Scotland. August 1994.

Stankus, P. and G.R. Wein. Hydrologic effects on species composition and productivity: a mesocosm approach. National Interagency Workshop on Wetlands. New Orleans, LA. April 1995.

Stibbe, S. and J V. McArthur. Hyporheic fauna of a southeastern blackwater stream. North American Benthological Society. Keystone, CO. June 1995.

Stockwell, C.A. and M.E. Mulvey. Preserving allelic diversity: are translocations successful? The Desert Fishes Council. Death Valley National Park, CA. November 1994.

Sugg, D.W. and R.K. Chesser. Gene dynamics in cyclic populations. Southeastern Association of Naturalists. Shreveport, LA. April 1995.

Taylor, B.E. **Invited.** Holocene climate and upland landscape evolution in upper coastal plain of South Carolina. 51st Annual Southeastern Archaeological Conference/39th Annual Midwest Archaeological Conference. Lexington, KY. November 1994.

Voos, G. , G.L. Mills, J. O'Neill, J. Johnson, and W. Jones. **Poster.** Organic molecular markers for estimating the biodegradation of petrolum hydrocarbons in soil. Soil Science of America. Seattle, WA. November 1994.

Voos, G., G.L. Mills, J. O'Neill, and W. Jones. **Poster.** Molecular markers as an index of petroleum biodegradation and microbial acitivity. American Society for Microbiology. Washington, DC. May 1995.

Weber, J.T., D.C. Adriano, and J. Albright. Coal ash utilization for soil amendment to enhance water relations and turf growth. American Society of Agronomy. Seattle, WA. November 1994.

Weber, J. , D.C. Adriano, and J. Albright. **Poster.** Coal Ash utilization for soil amendment to enhance water relations and turf growth. American Coal Ash Association. Orlando, FL. January 1995.

Wein, G.R. and B.S. Collins. Effect of shoreline topography on vegetation development in a planted cooling reservoir. National Interagency Workshop on Wetlands. New Orleans, LA. April 1995.

Wein, G.R. and B. Lemaster. **Poster.** Ecosystem Management on the Savannah River Site. Department of Energy. Washington, DC. March 1995.

Whiteman, H. Maintenance of environmentally-cued polymorphism promoted by gender-specific fitness payoffs. Society for the Study of Evolution. Montreal, Quebec, Canada. July 1995.

Wise, M.G., C. Wheat, B.M. Bundy, J V. McArthur, and L.J. Shimkets. Temporal variation in the genetic diversity and structure of a lotic population of *Burkholderia (Pseudomonas) cepacia.* American Society of Microbiologists. Washington, DC. May 1995.

Wohl, D.L., J.J. Hutchens, Jr., and J.B. Wallace. **Poster.** Changes in benthic invertebrate communities in an Appalachian Mountain stream continuum following a large storm. North American Benthological Society. Keystone, CO. June 1995.

Woodward, L.A., M. Mulvey, and M.C. Newman. **Poster.** Chronic mercury exposure: allozyme differentiation. Society of Environmental Toxicology and Chemistry. Denver, CO. November 1994.

IV. EDUCATION PROGRAM PARTICIPANTS

Undergraduate Research Participation Program - 1994

Russ Bodie	University of South Carolina, Columbia, SC	Vincent Burke/Dr. Whit Gibbons
Michelle Boone	Furman University, Greenville, SC	Dr. Gene Rhodes
Reide Corbett	Florida State University, Tallahassee, FL	Dr. Sue Clark
Jeffery Demuth	Harding University, Searcy, AR	Kurt Buhlmann/Dr. Whit Gibbons
Silvia Diaz-Conde	University of Nevada, Reno, NV	Dr. Steve Weeks
Joan Gariboldi	College of St. Francis, Joliet, IL	Dr. Domy Adriano
Scott Henry	University of Georgia, Athens, GA	Bobby Kennamer/Dr. I. Lehr Brisbin
Frederick James	Paine College, Augusta, GA	Cassie Bell/Dr. Tom Hinton
Charles Kean	Berry College, Mt. Berry, GA	Vincent Burke/Dr. Whit Gibbons
Angela Long	Memphis State University, Memphis, TN	Kathryn Gubista/Dr. Ron Chesser
Carrie McCracken	Drew University, Madison, NJ	Dr. Peg Mulvey
Charles Mitchell	Emory University, Atlanta, GA	Cassie Bell/Dr. Tom Hinton
Tracey Parker	Warren Wilson College, Asheville, NC	Mark Mills/Dr. Whit Gibbons
Christine Phelps	Eastern Michigan University, Ypsilanti, MI	Dr. Michael Newman
Jennifer Piascik	University of Georgia, Athens, GA	Dr. Justin Congdon
Christine Rabideau	St. Michael's College, Colchester, VT	Dr. Chuck Jagoe
Lisa Rania	St. Mary's College, Notre Dame, IN	John Krenz/Dr. Michael Smith
Travis Tuchak	Virginia Tech, Blacksburg, VA	John Lee/Dr. Whit Gibbons
Billy Webb	Clemson University, Clemson, SC	Dr. Michael Smith
Kate Wilson	Drexel University, Philadelphia, PA	Vincent Burke/Dr. Whit Gibbons
Gina Yanochko	Virginia Tech, Blacksburg, VA	Dr. Chuck Jagoe
Rebecca Wall	Ricks College, Rexburg, ID	Dr. J Vaun McArthur

TRAC - 1994 (Associated Western Universities)

Carole Bennett	Jesuit High School, Tampa, FL	Dr. Paul Bertsch
Dan Funsch	Alleluia Community School, Augusta, GA	Dr. John Pinder
Julie Mootz	St. Mary's School, Ft. Walton Beach, FL	Dr. John Pinder
Shahidur Rahman	Eskridge High School, St. Louis, MO	Dr. Domy Adriano
Julie Walker	Southport High School, Indianappolis, IN	Bobby Kennamer

Short-Term Graduate Research Participation Program - 1994

Michelle Bailey	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Vicky Batson	M.S.	Texas A&M, College Station, TX	Dr. Paul Bertsch
Loretta Battaglia	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Christopher Beck	Ph.D.	University of Georgia, Athens, GA	Dr. Justin Congdon
Matthew Brady	M.S.	Auburn University, Auburn, AL	Dr. Ron Chesser
Kurt Buhlmann	Ph.D.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Vincent Burke	Ph.D.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Anne Chazal	M.S.	Auburn University, Auburn, AL	Dr. Justin Congdon
Robert Cheney	Ph.D.	University of Georgia, Athens, GA	B. Dunning/Dr. Ron Chesser
Krista Clements	M.S.	University of Georgia, Athens, GA	Dr. Gary Meffe
Michael Draney	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Adrienne Edwards	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Aissa Feldmann	M.S.	University of Georgia, Athens, GA	Dr. Gary Meffe
Ron Hudson	M.S.	Texas A&M, College Station, TX	Dr. Gary Mills
Mark Komoroski	M.S.	University of Georgia, Athens, GA	Dr. Justin Congdon

John Lee	M.S.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Dean Lindholm	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Susan Miller	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Kim Orrell	M.S.	Virginia Tech, Blacksburg, VA	Dr. Justin Congdon
Victor Parrish	M.S.	University of Georgia, Athens, GA	Dr. Ken McLeod
Patrick Pierce	M.S.	University of Georgia, Athens, GA	Dr. Michael Smith
Margaret Plagowitz	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Gordon Plague	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Chris Salice	M.S.	Drexel University, Philadelphia, PA	Dr. Justin Congdon
Pamela Schultz	M.S.	University of Georgia, Athens, GA	Dr. Gary Mills
Michael Schwartz	Ph.D.	University of Maryland	Dr. Whit Gibbons
Julian Singer	M.S.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Susan Stibbe	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Craig Stockwell	Ph.D.	University of Nevada, Reno, NV	Dr. Peg Mulvey
William Straw	Ph.D.	University of Georgia, Athens, GA	Dr. John Pinder
Susan Turner	Ph.D.	University of Georgia, Athens, GA	Dr. Phil Dixon
Jennifer Wilson	Ph.D.	University of Georgia, Athens, GA	Dr. Winston Smith
Mark Wise	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Debra Wohl	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Rebecca Yeomans	Ph.D.	University of Georgia, Athens, GA	Dr. Justin Congdon

Long-Term Graduate Research Participation Program - 1994

Evelyn Gaiser	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Kathryn Gubista	Ph.D.	University of Georgia, Athens, GA	Dr. Ron Chesser
Christoper Harrison	Ph.D.	Texas A&M, College Station, TX	Dr. Whit Gibbons
Frank Hensley	Ph.D.	University of Florida, Gainesville, FL	Dr. Gary Meffe
Christopher Hudson	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Smith
Karen Kandl	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Smith
John Krenz	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Smith
Clark McCreedy	Ph.D.	Purdue University, West Lafayette, IN	Dr. I. Lehr Brisbin
Vicki Medland	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Mark Mills	Ph.D.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Thomas Risch	Ph.D.	Auburn University, Auburn, AL	Dr. Ron Chesser
Joel Snodgrass	Ph.D.	University of Georgia, Athens, GA	Dr. Gary Meffe
Julie Weis	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Lee Ann Woodward	Ph.D.	University of California, Davis, CA	Dr. Michael Newman

Faculty Research Participation Program - 1994

Stephen Dobson	Auburn University, Auburn, AL	Dr. Ron Chesser
James Gessaman	Utah State University, Logan, UT	Drs. Justin Congdon and I. Lehr Brisbin
Rod Kennett	Northern Territory University, Australia	Dr. Whit Gibbons
Joseph Rule	Old Dominion University, Norfolk, VA	Dr. Domy Adriano

Young Scholars - 1994 (University of South Carolina at Aiken)

Eddie Moore	Barnwell High School, Barnwell, SC	Tony Mills
Melissa Newman	Strom Thurmon High School, Edgefield, SC	Tony Mills

Undergraduate Research Participation Program - 1995

Natashia Bush	University of South Carolina, Aiken, SC	Dr. J Vaun McArthur
Jay Clark	Erskine College, Due West, SC	Dr. I. Lehr Brisbin
Jeff Charlton	University of Georgia, Athens, GA	Dr. Gary Wein
Daniel Connor	Georgia Tech University, Atlanta, GA	Dr. Tom Hinton
Raymond Danker	Clemson University, Clemson, SC	John Weber/Dr. Domy Adriano
Ronnie Devine	S. Carolina State University, Orangeburg, SC	Dr. Stephanie Fore/Dr. Beverly Collins
Alison Fiori	Duke University, Durham, NC	Dr. Whit Gibbons/Dr. Justin Congdon
Joshua Ford	St. Lawrence University, Canton, NY	Adrienne Edwards, Dr. Becky Sharitz
Jimmy Hill	Clemson University, Clemson, SC	Vincent Burke/Dr. Whit Gibbons
Ethan Jahnke	Colorado State University, Ft. Collins, CO	Dr. John Pinder
Katie Kurkjian	University of Georgia, Athens, GA	Thomas Risch/Dr. Ron Chesser
Angela Lueking	University of Nebraska, Lincoln, NE	Dr. Sue Clark
Alison Moulding	Duke University, Durham, NC	Dr. J Vaun McArthur
Jeannine Ott	University of Georgia, Athens, GA	Dr. Whit Gibbons
Kevin Palmer	Georgia Southern University, Statesboro, GA	Dr. Peg Mulvey
Christine Rabideau	St. Michael's College, Colchester, VT	Dr. Charles Jagoe
Erin Reat	Texas Tech University, Lubbock, TX	Dr. Gene Rhodes
Laurian Schwallie	University of Virginia, Charlottesville, VA	Dr. Paul Bertsch
Grace Yu	Georgia Tech University, Atlanta, GA	Dr. Sue Clark

Short-Term Graduate Research Participation Program - 1995

Joseph Albright	Ph.D.	University of Georgia, Athens, GA	Dr. Domy Adriano
Michelle Bailey	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Christopher Beck	Ph.D.	University of Georgia, Athens, GA	Dr. Justin Congdon
Jennifer Broft	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Kurt Buhlmann	Ph.D.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Vincent Burke	M.S.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Anne Chazal	M.S.	Auburn University, Auburn, AL	Dr. Justin Congdon
Krista Clements	M.S.	University of Georgia, Athens, GA	Dr. Gary Meffe
Reide Corbett	M.S.	Florida State University, Tallahassee, FL	Dr. Sue Clark
James DeWoody	Ph.D.	Texas Tech University, Lubbock, TX	Dr. Ron Chesser
Michael Garrett	M.S.	University of Georgia, Athens, GA	Dr. Gary Mills
David Hernandez	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Smith
Kevin Holloman	Ph.D.	University of Georgia, Athens, GA	Dr. Brisbin/Dr. Dallas
Karen Kandl	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Smith
John Kind	M.S.	University of Georgia, Athens, GA	Dr. Cham Dallas
Mark Komoroski	Ph.D.	University of Georgia, Athens, GA	Dr. Justin Congdon
John Krenz	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Smith
Dean Lindholm	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Susan Miller	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Debra Moore	Ph.D.	University of Alabama, Birmingham, AL	Dr. Whit Gibbons
Jennifer Olson	M.S.	Texas A&M, College Station, TX	Dr. Gary Mills
Victor Parrish	M.S.	University of Georgia, Athens, GA	Dr. Ken McLeod
Melissa Pilgrim	Ph.D.	Southeastern Louisiana University	Dr. Whit Gibbons
Margaret Plagowitz	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Gordon Plague	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Pamela Schultz	M.S.	Clemson University, Clemson, SC	Dr. Gary Mills
Michael Schwartz	M.S.	University of Georgia, Athens, GA	Dr. Domy Adriano
Julian Singer	M.S.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz

Susan Stibbe	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Christopher Tatara	Ph.D.	University of Georgia, Athens, GA	Dr. Michael Newman
Susan Turner	Ph.D.	University of Georgia, Athens, GA	Dr. Phil Dixon
Gordon Ward	Ph.D.	University of Georgia, Athens, GA	Dr. Phil Dixon
Debra Wohl	Ph.D.	University of Georgia, Athens, GA	Dr. J Vaun McArthur

Long-Term Graduate Research Participation Program - 1995

Loretta Battaglia	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca Sharitz
Michael Draney	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Adrienne Edwards	Ph.D.	Texas A&M, College Station, TX	Dr. Rebecca Sharitz
Aissa Feldman	M.S.	University of Florida, Gainesville, FL	Dr. Gary Meffe
Robert Ford	Ph.D.	Clemson University, Clemson, SC	Dr. Paul Bertsch
Evelyn Gaiser	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Kathryn Gubista	Ph.D.	University of Georgia, Athens, GA	Dr. Ron Chesser
Christoper Harrison	Ph.D.	Texas A&M, College Station, TX	Dr. Whit Gibbons
John Lee	M.S.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Clark McCreedy	Ph.D.	Purdue University, West Lafayette, IN	Dr. I. Lehr Brisbin
Vicki Medland	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Mark Mills	Ph.D.	University of Georgia, Athens, GA	Dr. Whit Gibbons
Thomas Risch	Ph.D.	Auburn University, Auburn, AL	Dr. Ron Chesser
Joel Snodgrass	Ph.D.	University of Georgia, Athens, GA	Dr. Gary Meffe
Lee Ann Woodward	Ph.D.	University of California, Davis, CA	Dr. Michael Newman

Faculty Research Participation Program - 1995

Steven Clasen	Monument Valley High School, Kayenta, AZ	Dr. John Pinder
Will Connor	Clemson University, Clemson, SC	Dr. Ken McLeod
Diane DeStevens	University of Wisconsin	Dr. Rebecca Sharitz
Stephen Dobson	Auburn University, Auburn, AL	Dr. Ron Chesser
Robert Jones	Virginia Polytechnic University	Dr. Rebecca Sharitz
Frank Kinard	College of Charleston, Charleston, SC	Dr. Sue Clark
Ronald Mumme	Allegheny College, Meadville, PA	Dr. Beverly Collins
Richard Seigel	Southeastern Louisiana University	Dr. Whit Gibbons

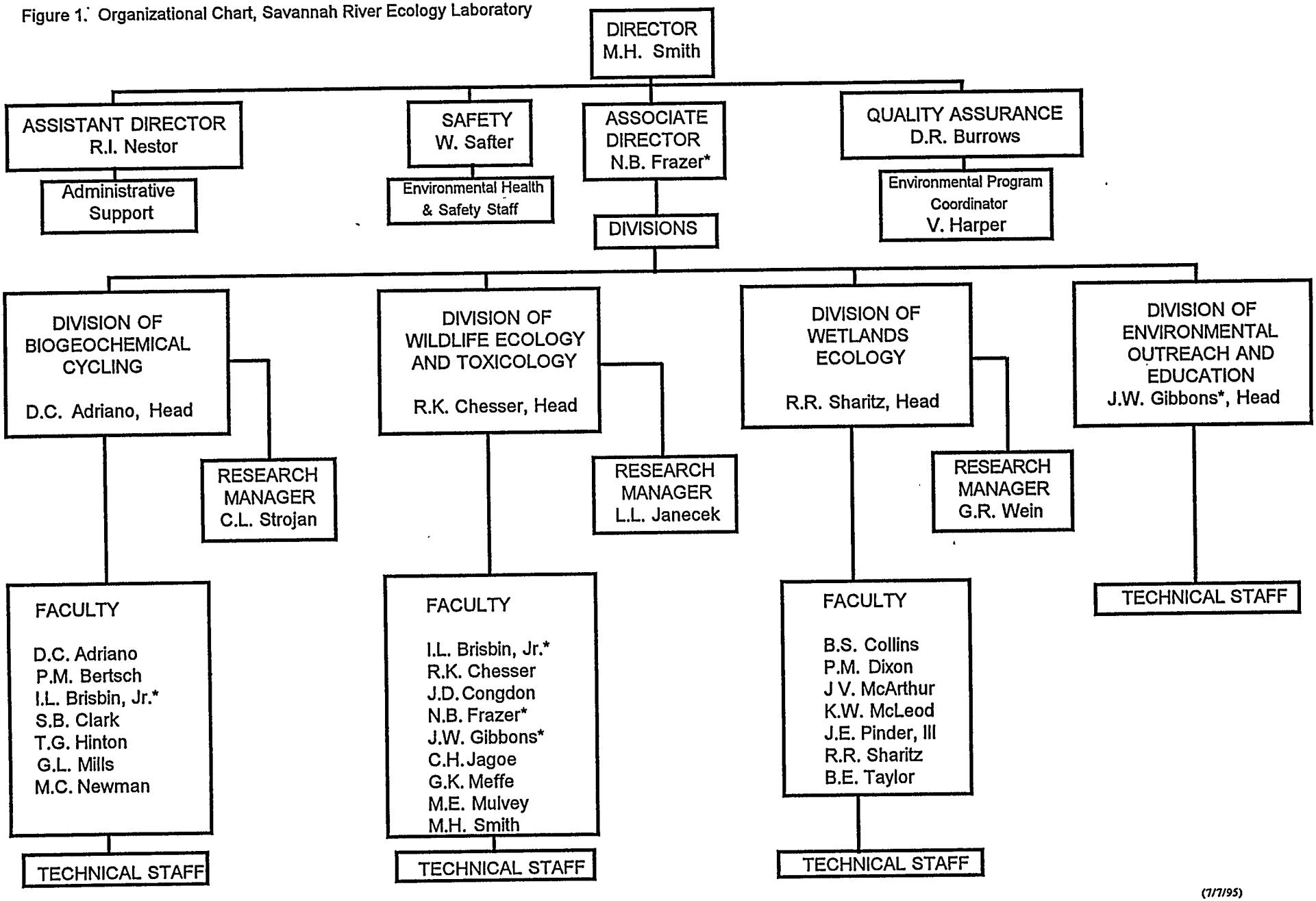
High School Research Participation Program - 1995

William Moretz	Augusta Preparatory Day School, Augusta, GA	Vincent Burke/Dr. Whit Gibbons

High School DOE Interns - 1995 (Claflin College)

Sean Dennis	LBJ Science Academy, Austin, TX	Dr. Tom Hinton
William Gostylo	Chapel Hill-Chauncy Hall School, Waltham, MA	Dr. Domy Adriano
Emily Hopp	Richmond County Alternative, Augusta, GA	Jane Sanders
Kathryn Komoroski	Athens Montessori Middle School, Athens, GA	Dr. Justin Congdon

Figure 1. Organizational Chart, Savannah River Ecology Laboratory



(7/7/95)

*Denotes joint affiliation