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Michael H. Smith, Director

DISCLAIMER

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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 (SRS) near Aiken, South Carolina. Significant accomplishments were made during the past year in the areas of research, education and service.

The Laboratory's research mission was fulfilled with the publication of two books and 143 journal articles and book chapters by faculty, technical staff, students, and visiting scientists. An additional three books and about 80 journal articles currently are in press. Faculty, technician and students presented 193 lectures, scientific presentations, and posters to colleges and universities, including minority institutions. Dr. J Vaun McArthur organized and conducted the Third Annual SREL Symposium on the Environment: *New Concepts in Stream Ecology: An Integrative Approach.* Dr. Michael Newman conducted a 5-day course titled *Quantitative Methods in Ecotoxicology*, and Dr. Brian Teppen of The Advanced Analytical Center for Environmental Sciences (AACES) taught a 3-day short course titled *Introduction to Molecular Modeling of Environmental Systems.* Dr. I. Lehr Brisbin co-hosted a meeting of the Crocodile Special Interest Group. Dr. Rebecca Sharitz attended four symposia in Japan during May and June 1996 and conducted meetings of the Executive Committee and Board of the International Association for Ecology (INTECOL).

The research divisions at SREL continue to progress. Scientists from the Division of Wildlife Ecology and Toxicology continued to conduct research at the Chernobyl nuclear site in Ukraine on the genetic effects of radiation on animal populations; this research was featured in several television and radio broadcasts by ABC, CNN, NPR, and BBC. Research conducted in the Division of Wetlands Ecology identified a new family of Isopods from the hyporheic aquatic zone beneath a stream on the SRS. This group's nearest living relative is found in Eastern Europe in a similar habitat. The Advanced Analytical Center for Environmental Sciences (AACES) successfully completed its second year. This center will include a modern laboratory and user facility for the innovative application of advanced instrumentation to address environmental concerns.

The Savannah River Ecology Laboratory played a pivotal role in the development of proposals for three Centers of Excellence at the Savannah River Site. These centers include the National Water Research Center, Soil Remediation Research Center, and the International Initiative in Radioecology. Membership in these centers includes SREL and the Education Research and Development Association of Georgia Universities (ERDA) and South Carolina Universities Research and Education Foundation (SCUREF).

A major activity for SREL in FY96 has been the development of a new Cooperative Agreement between the U.S. Department of Energy and the University of Georgia to replace the existing Management and Operating (M&O) contract. The M&O contract under which SREL has operated through the UGA Research Foundation has been in effect since 1973. It was the longest running contract on the SRS and has brought over $130 million into the University of Georgia system. The new Cooperative Agreement went into effect on July 1, 1996 and should provide SREL greater flexibility in operating within the DOE structure.

Several faculty members were awarded for their scientific achievements. Dr. Tom Hinton has

been invited to a two-year term as a member of the Citizens Advisory Committee on public health and research activities at Department of Energy Sites. Dr. Whitfield Gibbons was presented the State of South Carolina Environmental Awareness Award by Governor David Beasley and was elected President-Elect for the Association of Southeastern Biologists. Dr. Sue Clark was appointed to the National Academy of Sciences Committee on the Waste Isolation Pilot Plant. Dr. Clark also, received a 1995 DOE Health Physics Faculty Research Award. Drs. Michael Newman and Gary Meffe were promoted to Senior Research Scientist at the University of Georgia.

Participants in SREL's education program during 1995 and 1996 came from schools located throughout the United States and included 20 undergraduate students, 42 graduate students, 5 pre-college teachers, 3 visiting faculty and 2 high school students. These participants come from nearly half of the states, emphasizing the national stature of the SREL program. SREL was awarded a National Science Foundation award from the Research Experiences for Undergraduates Program for a proposal titled *The impact of energy technologies on natural environmental systems*, in April 1996. This award was used to support undergraduate education in the summer of 1996.

In addition to holding faculty positions at The University of Georgia, various SREL faculty have adjunct status at 23 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 1996, Outreach staff gave more than 300 presentations to schools, civic groups and similar audiences. This year, the Division received an award from the CSRA Chapter of the Society of Professional Journalists for the "Best PR Magazine". This award recognized the lab's publication titled *Biodiversity: Prospect and Promise for the Savannah River Site--A National Environmental Research Park.*

Major additions to SREL facilities were completed that will enhance the Laboratory's work in the future. Construction on a 5,000 ft^2 laboratory addition is nearing completion. The three new multiuser laboratories will have research initiatives in molecular ecology and bioremediation, and triple the space available for analytical equipment. A new, 5,000 ft^2, animal care facility is being constructed and is slated to be completed this fall. Construction of a new 3,500 ft^2 receiving building was completed and the old receiving complex has been converted to offices. A 3,500 ft^2 building has been purchased to house a four-classroom Distance learning Center and the newly purchased hardware for the center is to be installed and operational early this fall. The 5,000 ft^2 multi-purpose conference center that was funded by the University of Georgia Research Foundation (UGARF) has continued to be developed with the completion of landscaping and additional parking. The Conference Center has seen wide use, both by SREL and the local community. The facility was used to host a total of 82 scientific meetings and environmental education programs for students, teachers and the general public. Funding and initial plans for a greenhouse renovation and expansion in have been approved by DOE.

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. The VAX based computer system was converted to a client-server system. This system continues to develop as an electronic network for communication, scheduling, and budget management. An internal performance review was completed for the Laboratory Director. An internal evaluation of the current laboratory organization has been initiated to assess its relevance to the changing DOE/SRS mission.

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

Fourmile Branch Natural Recovery

K. W. McLeod, K. T. Barnett, T. G. Ciravolo, and J. K. McCarron

Since 1985, when C-Reactor was shutdown, the vegetation of the Fourmile Branch delta has been recovering. Several surveys of the vegetation have been conducted, beginning in 1987. During the summer of 1996, the 38 permanent plots in the delta were resurveyed. The list of species has not changed drastically over the years, but the relative abundances and distribution of the species has. Locations near the center of the delta which had no woody species in 1987 are now populated by several early successional woody species, with wind-dispersed seeds. Several shrub and tree species (black willow, ash, and buttonbush) that are very characteristic of disturbed wetland areas are distributed throughout the delta. In some of the denser willow stands in the delta, there is also considerable mortality of smaller stems. Near the least disturbed outer margin, older baldcypress and water tupelo are still present in low numbers and both species have established seedlings and saplings. Scattered throughout the disturbed area are many loblolly pine trees found in selected locations, higher in elevation and near the undisturbed upland margin.

On the lower side of the delta, two reference plots were included which are higher in elevation. Several species of oak and hickory are found in these locations, but there is no evidence that these species are establishing in disturbed areas only a few meters away. Also, on this lower side were found very dense stands of loblolly pine in the 1993 survey which were not found in 1987. These stands are self thinning and currently have only a third to half of the stems present in 1993.

The Fourmile Branch delta is undergoing typical secondary succession for a highly disturbed wetland. The latter successional species are not invading this habitat. Succession will eventually lead to a closed canopy forest, but it will not be present for a long time. Thus, if earlier canopy closure is desirable, then some effort to establish these latter successional tree species will be necessary.

Swamp Forest Recovery Following Disturbance

R. R. Sharitz, C. J. King and D. De Steven

Studies of the impacts of industrial activities on the Savannah River Site (SRS) to ecological systems, and the recovery of these systems following reactor closure, provide a valuable baseline for assessing the ability of natural ecosystems to withstand disturbance and the need for restoration and/or remediation. Although research has focused on the effects of nuclear reactor operations, much of the knowledge gained is transferable to other types of industrial activities . During the 40 year period of SRS nuclear reactor operations, cooling-system waters were discharged into streams flowing into the floodplain of the Savannah River, destroying large areas of the original swamp forest. Since reactor shutdown, research on wetland restoration and on natural recovery of wetlands has been conducted to establish a framework for larger-scale restoration efforts. Two projects described here, one in Fourmile Branch delta and the other in the lower part of the Pen Branch delta, have been conducted to assess the pattern and rate of natural swamp forest recovery.

Vegetation in permanent plots established in 1987 in the corridor and delta of Fourmile Branch have been sampled periodically. Color infrared aerial photographs form 1985, 1990, and 1993 have been rectified and classified using Earth Resources Data Analysis System (ERDAS) Remote sensing technology. Data from these two sources were combined to examine the site and pattern of plant succession following shutdown of C-Reactor in 1985. Between 1985 and 1993, tree and shrub coverage in the 60 ha Fourmile delta study area has increased from 3 ha to 33.5 ha. Woody species establishment has been most rapid within 50 m of the surviving forest around the edge of the disturbed area; thus, most recovery is the result of dispersal of seeds from nearby sources rather than from surviving propagules in the delta sediments. Although the establishment of woody vegetation is proceeding steadily, the primary tree species are loblolly pine (*Pinus taeda*) and willow (*Salix spp.*), both early-successional trees that are wind-dispersed. There has been very limited recovery of the original hardwood and swamp forest canopy species.

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

Comparison of the successional process in these two thermally disturbed floodplain forests confirms that canopy species recovery depends greatly on the post-disturbance hydrologic condition (in this case timing and duration of floods), substrate conditions , and availability of propagules. When surviving trees provide at least some seed input, canopy species recovery is proceeding more rapidly and artificial restoration is not needed.

Carolina Bay Restoration

R.R. Sharitz, G.R. Wein, and R.E. Lide

Although there are thought to be 10,000 to 20,000 Carolina bays (isolated depression wetlands) in the southeastern U.S. Coastal Plain, most of these wetlands have been functionally altered through ditching, draining and/or other disturbances. Of the nearly 400 such depression wetlands on the SRS, many were drained by previous landowners and converted to agricultural use. As a result, these bays are no longer dominated by wetlands species, nor do they meet many natural wetland functions.

The restoration of Carolina bays may serve to mitigate other wetland losses. Furthermore the restoration of drained bays may be achieved more easily and cost-effectively than the restoration of more highly disturbed wetlands. SREL, with cooperation from SRFS, has developed a research program to evaluate efficient methods for restoring Carolina bay wetlands and management practices that may enhance restoration. A four-hectare Carolina bay (Bay 93) supported herbaceous marsh

vegetation in 1951, according to surveys of aerial photography. Drainage of the bay since that time has permitted invasion of upland species, including loblolly pine and sweetgum. In November 1993, the ditch in Bay 93 was plugged to restore the hydrology approximately 50% of the timber was removed and 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 hydrology was more typical of undrained bays, and the vegetation was characterized by more wetland herbaceous species. The increased light and soil disturbance created by the removal of the forest vegetation and the burning stimulated germination of herbaceous species from the seed bank and accelerated recovery of the herbaceous marsh in these treatments. These results suggest that if wetland species remain in the seed bank of the disturbed wetland, vegetation recovery may be relatively quick once the hydrology has been restored. Thus, these Carolina bay systems, may be paretically appropriate for restoration and mitigation purposes.

Carolina Bay Hydrology and Vegetation

B.S. Collins

The marsh vegetation of herbaceous Carolina bays is made up of floating-leaved perennials and emergent annuals and perennials. From year to year, composition of the vegetation is influenced by interaction of bay hydrology with the seed and propagule bank. The seed and propagule bank is a potential community. Timing and duration of bay filling and drawdown determines extant vegetation. Long periods of flooding 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 is currently 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 was 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. Seedbank and vegetation relationships have been examined by censusing vegetation in the bays at the core sampling points.

After one year, the number of plant species from the cores differed among bays and water level treatments, but not among sampling points. Unflooded cores were most rich and flooded cores least rich. The plant community from flooded cores was primarily floating-leaved aquatic herbs and perennial emergent grasses. Unflooded cores had few floating-leaved plants and were a mix of wetland grasses, sedges, and herbs. Bay vegetation also differed among bays, and, as well, among sampling points. Points most likely flooded had no vegetation or floating-leaved aquatic plants.

Least likely flooded points had a larger component of upland vegetation, and intermediate points had aquatic and emergent vegetation. In a year, vegetation from the propagule bank appears to reflect the duration and depth of spring flooding, and, in bays, is zoned with increasing distance from the center of the bay.

Aquatic Invertebrate Biodiversity of Upper Three Runs Creek and Contaminated Streams

J V. McArthur

Restoration of Pen Branch is an intensive project involving researchers from USFS, USC-Aiken, Auburn University, Clemson University and SREL. Our efforts last year involved initiating a comprehensive survey of macroinvertebrate communities. Monthly samples were collected from artificial snag samplers and from the macrophyte beds along the stream. These samples are currently being processed and represent the best macroinvertebrate data from Pen Branch. Dissolved organic carbon samples were collected and estimates of primary production based on chlorophyll a concentrations were made. All wood and macrophyte beds were mapped and measured to estimate their respective impacts on the stream. In addition we have designed a large scale manipulation of the lowest reach of Pen Branch to determine the effect of increased wood, organic matter input and shading on the recovery dynamics of macroinvertebrates. This experiment will be conducted along with the USFS.

In addition to the macroinvertebrate survey studies we have begun a survey of Actinomycete bacteria in Pen Branch and other streams on the SRS. These microorganisms are important to stream function as they are primarily responsible for chitin degradation. These organisms can affect ecosystem level processes by controlling fungi (high chitin content in cell walls). Additionally actinomycetes produce antibiotics. From previous studies we have shown a decrease in antibiotic resistance in disturbed streams such as Pen Branch. We are surveying isolates from these streams for unique antibiotics.

Salt Stress on Wetland Woody Species

K. W. McLeod and J. K. McCarron

Salts are introduced into ecosystems in a wide variety of manners, ranging from anthropogenic introductions (such as chemicals releases, fertilization, salt water intrusion) to natural events (tidal activity, hurricanes). The impact is dependent on which salt, its concentration, length of exposure, abiotic conditions, and topography of the ecosystem. To examine for salt effects, there are usually two aspects about which to be concerned: the toxicity of the salt and the osmotic effect of the salt. While the toxicity of a specific concentration of salt is important to know, the more useful information is in the effects of the sublethal salt concentrations. For instance, most salts when added to the soil will affect water relations of plants, subjecting them to a "physiological drought due to the increased difficulty in absorbing water from the soil. Thus, the sublethal effects can alter plant productivity, which ultimately may prove to be lethal, but may not expressed for several years.

Over the past year, this program has examined several aspects of the response of baldcypress to increased soil salt concentrations. Saline water was added to potted bald cypress grown in unsaturated, saturated, and flooded soils. The initial effect on photosynthetic rates and water relations were dependent on the potential for the saltwater to infiltrate the soil matrix. For plants grown in unsaturated conditions, saltwater moved immediately into the soil and decreased photosynthesis, stomatal conductance and pre-dawn xylem pressure potential. Reductions in photosynthesis and stomatal conductance were due to lower xylem pressure potential for plants in unsaturated and now saline soil. Plants growing in saturated or flooded soils showed no initial physiological response to the salt since there was no immediate increase in soil salinity.

After several weeks the saline water infiltrated into the flooded soils and affected physiological activity, but the salt water in the saturated soil was allowed to drain off. The soil did not increase in salinity and no physiological effects were observed. Plants growing in both unsaturated and flooded soils now had higher soil salt concentrations and 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 dilution over time.

No mortality was observed by the treatments and the following spring, no significant treatment effects in any physiological parameter were observed. When this acute salt addition was repeated the following year, very similar results were obtained, without any obvious cumulative effects of two salt exposures.

Germination of baldcypress seed was also examined following salt water exposure and was found to be delayed (probably an osmotic effect in lowering imbibition rate), with a reduced percent germination (potential salt toxicity) and a lower overall survival rate of those seed which germinated.

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A.2 ENVIRONMENTAL ORGANIC CHEMISTRY STUDIES RELATED TO THE DEFENSE WASTE PROCESSING FACILITY

Abiotic Transformations of Tetraphenylborate in the Environment

G.L. Mills

Studies conducted in this research program component examine the reactions of contaminant organic compounds in the environment. Specifically, these studies seek a better understanding of the mechanisms by which these reactions take place, the abiotic and biotic factors that affect the rates of these reactions, and the relationships between molecular structure of the organic compounds and their reactivity in these processes. The information generated by these studies will contribute to the development of models to predict the mobility and transformations of organic contaminants in the environment and consequently, enhance our ability to assess both ecological and human health risks. These reactions include abiotic reactions such as sorption, photolysis, oxidation, and reduction, as well as biological transformations.

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.

The rates of indirect photolysis of organic compounds often follow an apparent first-order kinetic model where C is the substrate concentration and ks is the apparent first-order rate constant. In general, the reaction rates can be described by the first-order rate equation when the substrate 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 [X] is maintained at a steady state concentration where $[X]_{ss}$ is the steady-state concentration of reactive transient produced by the sensitizer and k_2 is the second-order rate constant. Information regarding reaction pathways can be gleaned by the addition of compounds known to interact selectively with a specific reactive transient oxidant and consequently change the steady state concentration and measured ks.

The indirect photolysis of tetraphenylborate (TPB) in humic acid solutions followed apparent first-order kinetics in all of our experiments. The enzyme superoxide dismutase (SOD) catalyzes the disproportionation of the super oxide anion in the following reaction:
$2O_2^- + 2H^+ \longrightarrow H_2O_2 + O_2$ and can used to investigate the role of superoxide anion in indirect

photolysis. The oxidation rate of TPB in humic acid solutions containing SOD (50 mg/L) was not significantly different ($P<0.05$) than in the control solutions containing only humic acid. Thus, reaction paths involving superoxide anion are a negligible contribution to the humic acid sensitzed photolysis.

The effects of sodium azide and D_2O on the sensitized photoxidation were determined to evaluate the intermediacy of $^1O_2$ in the reaction. The azide anion quenches $^1O_2$ thus reducing $[^1O_2]_{ss}$ and resulting in a slower reaction rate. Water also physically quenches $^1O_2$ to $^3O_2$. Due to the isotope effect, mixtures of D_2O/H_2O result in a slower rate of quenching and consequently should increase the rate of oxidation. The rate constant, k_s, calculated for the solution containing 1.0 mM NaN_3 was 35% less than the value obtained for the solution containing only humic acid and suggests that $^1O_2$ contributes to the indirect photoxidation of TPB. However, the expected increase in k_s in the D_2O/H_2O (90/10 v/v) mixture was not observed. A rapid rate of indirect photolysis was measured when rose bengal, an organic dye known to sensitize the production of $^1O_2$, was present in solution. This confirms that TPB can degrade via a pathway involving $^1O_2$; however, the intermediacy of $^1O_2$ in the humic acid sensitized reaction remains equivocal.

Three reaction products were identified from the results of the Gas Chromatography-Mass Spectroscopy analysis of the hexane and ethyl acetate extracts. Biphenyl and -terphenyl were identified in the hexane fraction based on comparison of the mass spectra and chromatographic retention times with reference standards. Several peaks were present in the total ion chromatogram from the ethyl acetate extract. Triphenylboron was identified based on the agreement of the mass spectrum and retention time with a reference standard. We have tentatively identified a second product in this fraction as bis-diphenylborinate based on our assignment of the major ion fragments in the mass spectra. We evaluated the possibility that the observed products may have resulted from the thermal decomposition of TPB in the injection port of the gas chromatograph. None of the observed products were produced by the injection of a TPB standard. A product yield of 10% was calculated for o-terphenyl based on the response of a reference standard and assuming a 1:1 stoichiometric relationship with TPB. This can only be viewed as an estimate since the reaction mechanisms and pathways are unknown.

Recent Publications: Environmental Organic Chemistry

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Mills, G.L., C.P. Wolfe, and B.R. Dalton. 1995. Free and humic-bound carbohydrates leached from leaves of four floodplain tree species. Communications in Soil Science and Plant Analysis 26:3335-3341.

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A.3 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 quantify 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. This research provides site-specific data for DOE and WSRC upon which sound human and ecological risk analyses can be conducted.

Primary results

Par Pond

- The draw down of PAR pond reservoir exposed 5 km² 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, continued thorough refill (August 1994 to March 1995), and are still ongoing. Concentrations of ^{137}Cs in bass doubled after the draw down, and subsequently decreased to pre-draw down levels following refill. A manuscript on ^{137}Cs dynamics in fish as affected by the changing water level of Par Pond is now in preparation. We suspect that the ^{137}Cs dynamics were altered because nutrient rich Savannah River water was no longer pumped into the reservoir, and because of changes in water volume relative to the area of contaminated sediments.
- Concentration Ratios(CR) (Bq ^{137}Cs kg^{-1} plant / Bq ^{137}Cs kg^{-1} soil) derived from plants growing on the exposed lake bed were among the highest reported within the literature, with some CR reaching 365. The low organic matter, low pH, and low K in the sandy, kaolinite sediments are likely reasons for the very high CR. A principal components analysis revealed that concentrations of ^{137}Cs in plants were significantly correlated to soil concentrations of K, Na, ^{137}Cs, and pH.
- Experiments were conducted on the transfer of ^{137}Cs and ^{90}Sr from 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 was conducted in collaboration with Dr. Ward Whicker at Colorado State University.
- Sequential extractions were performed on sediments associated with the concentration ratio study mentioned above, and with soils subjected to different agricultural amendments in a garden study that used Par Pond sediments. The sequential extraction results identified various soil fractions to which ^{137}Cs was attached, and allow better predictions of plant uptake and long-term contaminant mobility.

Pond A

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

Mesocosm Experiment

- We completed the field portion of a mesocosm study designed to determine how changes in water quality and fluctuating water levels 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. The laboratory analyses of soil samples from the study are completed. Analyses of plant samples are continuing.

Other SRS Systems

- Intensive field sampling of Ponds B, C, 5, and L-Lake were done semiannually for radionuclides. These data serve as controls or comparative sites for studies conducted at Par Pond.
- We completed work on the *Temporal Trends of ^{137}Cs in an Abandoned Reactor Cooling Reservoir*. The research determined ^{137}Cs inventories in Pond B and compared ecological half-lives of the contaminant to those predicted by Dr. Whicker 10 years ago when he conducted extensive work there. The research was in collaboration with Colorado State University.

Radionuclide Environmental Chemistry

S.B. Clark

The quantity and chemical form of hazardous metals and 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. 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.

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 processing controlling contaminant fate.

3. Frequently, methods to accomplish objective 1 and 2 are not available. Thus we also have continued to develop 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.

This year, new research was begun to develop analytical screening methods for determining gross alpha and beta contamination in environmental samples. A fast reliable method is necessary to screen for the large volume of contaminated material expected to be generated in remediation efforts. We have developed a method for direct counting of soils with proportional counting, which is being implemented by the Environmental Monitoring Section of WSRC. We are currently working on liquid scintillation technique for screening swipes collected by Health Protection during radiological surveys, and for counting soil leachates. We have published our work on sequential extractions, and the graduate student involved in that program is currently on the faculty of University of Nevada at Las Vegas and is funded by DOE for research related to the Nevada Test Site.

Using data generated with our sequential extracting method, we are developing a model to predict the transport of U, Am, and Cm in contaminated SRS ecosystems. Our experimental results indicate that ion exchange is a dominant mechanism in acidic natural systems, which are typical of the SRS. This allows us to now develop a more simplified model for predicting fate and transport under acid conditions. The simplified ion exchange model will not require the extensive data base generally necessary when using models based on surface complexation.

Finally, Dr. Clark continues to serve on the National Academy of Science/National Research Council Committee for the Waste Isolation Pilot Plant (WIPP). The WIPP is the intended repository for the nation's transuranic waste, and DOE is filing a license application to the Environmental Protection Agency to allow shipment of waste to WIPP for storage. The NAS/NRC Committee on which Dr. Clark serves will issue a report this fall concerning the application process, and DOE's scientific and technical basis for disposal of transuranic waste in this manner.

Resuspension And Bioavailability of Contaminated Soil

T.G. Hinton

This research examines the resuspension of contaminated soil particles onto vegetative surfaces. Our goal is to determine when inadvertent ingestion of soil by grazing animals might

constitute an important pathway of contaminant intake. We are also interested in the bioavailability of contaminants attached to soil particles, particularly in determining if sequential extraction techniques can be used to predict biological availability.

Progress

- We received a new ultra low level liquid scintillation counter at Par Pond Laboratory. The instrument will be used for ^{90}Sr analyses. We learned how to use the instrument, prepared ^{90}Sr standards and developed a technique for quantifying ^{90}Sr in plants during 1996.
- Foliar absorption of ^{90}Sr from a resuspended source was quantified and compared to other pathways by which plants can become contaminated. The importance of this pathway for ^{90}Sr was compared to ^{137}Cs. Analyses were conducted on plants from the Chernobyl region.
- A comparative spatial analysis of Hg and ^{137}Cs within the Hot Arm of PAR Pond was conducted. The analyses demonstrated the use of variance propagation as a tool to develop an efficient sampling regime.
- Daniel Conner, Georgia Institute of Technology, worked on methods of obtaining particle size distribution of soils resuspended onto plant surfaces. Our technique development continues to be plagued with equipment troubles. Techniques that are quantitative prove to be impractical for routine use due to intensive labor requirements or expense of analyses.

Plans for 1997

- The resuspension work will be terminated this year, and efforts will concentrate on publishing the results generated to date. Plans are to shift directions and concentrate research on ecological risk analyses.

Recent Publications

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Bryce, A.L. and S.B. Clark. 1996. Nickel desorption kinetics from hydrous ferric oxide in the presence of EDTA. Colloids and Surfaces A: Physicochemical and Engineering Aspects 107:123-130.

Clark, S.B., W.H. Johnson, M.A. Malek, S.M. Serkiz, and T.G. Hinton. An evaluation of sequential extraction procedures to estimate geochemical controls on the mobility of fission product and actinide contaminants in soil fractions of natural systems. *Radiochimica Acta.* in press

Herbert, B.E. and P.M. Bertsch. 1995. Characterization of dissolved and colloidal organic matter in soil solution: A review. p. 63-88. *In:* Eighth North American Forest Soils Conference: Carbon Forms and Functions

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Howard, B., N. Assimakopoulos, N. Crout, T. Hinton, K. Hove, R. Mayes, C. Vandecasteele, G. Voigt, and F. Zelenka. 1995. Transfer of radionuclides in animal production systems. Final Report to EU Nuclear Fission Safety Programme (F13p-CT92-0006). Brussels, Belgium.

Kelly, M.S. and J.E. Pinder, III. 1996. Foliar uptake of ^{137}Cs from the water column by aquatic macrophytes. Journal of Environmental Radioactivity 30:271-280.

Pinder, J.E., III, J.W. Bowling, R.L. Lide, and L.M. Beatty. 1995. The distribution of ^{137}Cs in sediments of the littoral zone of a former reactor cooling pond. Journal of Environmental Radioactivity 28:57-71.

Rauret, G., R. Alexakhin, N. Arkhipov, A. Cremers, S. Frisakova, T.G. Hinton, L. Moberg, B. Prister, and C. Vandecasteele. 1995. Transfer of radionuclides through the terrestrial environment to agricultural products, including the evaluation of agro-chemical practices. Final Report to the Commission of European Communities (ECP-2), Brussels, Belgium.

Sowder, A.G., S.B. Clark, and R.A. Fjeld. The effect of silica and phosphate on the transformation kinetics of schoepite to becquerelite and other phases. Radiochimica Acta (in press).

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

A.4 DATABASE SYNTHESIS

Research Data Archive Activities

R.K. Chesser and J. Heuer

The major activity within the SREL Data Archive Program during FY96 was the design, testing and deployment of a archive information application of the SREL Research Data File Catalog System. SREL data archive information is now readily available over the Lab Novell network via most PC workstations. The original application was completely redesigned and no data from the original database was lost. The new application facilitates a much greater involvement by the faculty custodians and researchers. This should enhance the accuracy of the information by minimizing communication errors and should eventually promote a more timely inclusion of information in the archive file catalog. The new application utilizes a desktop computing platform familiar to nearly all of the research personnel and eliminates the need to learn a separate computer operating system just to "officially" document research data files.

Inclusion of historical and new research information continued during FY96. However, due to limited manpower and the demands of program development and revision, inclusion of most studies submitted during this year was postponed pending final completion of the application and is, therefore, still underway. The Research Data File Catalog has information on over 330 studies covering over 1,100 separate data files.

While there were no requests for information from the archives from non-SREL scientists, the archive continued to provide a valuable source of information for laboratory personnel. On two occasions, researchers investigating potential new research initiatives acquired essential data and supporting documentation from the archive.

The SREL Data Archive Program plans to provide a link to information in the archive data file catalog via a proposed internal World Wide Web homepage. Also, plans are underway to design a Geographic Information System (GIS) interface for research archive information and to provide map-oriented location information for the selected research data files documented in the archive.

Studies Included in the SREL Data Archive System during 1996

The following studies were submitted for inclusion in the SREL research data archive system during FY96.

Custodian	Brief Title
Jagoe	Fish erythrocyte study
Jagoe	Effect of Hg on gill morphology
Jagoe	Carolina bay water quality study
McArthur	Comparative colonization rate study
McArthur	Organic matter retention by macrophytes
Meffe	Tadpole lipid study

Jagoe	Carolina bay water quality study
McArthur	Comparative colonization rate study
McArthur	Organic matter retention by macrophytes
Meffe	Tadpole lipid study
Mulvey	Chironomid genetics study for Clear Lake, CA
Chesser	Genetic damage in catfish from Chernobyl, Ukraine
Collins	Craig's Pond pitcher plant study
Collins	Craig's Pond moisture gradient study
Collins	Pond woody vegetation study
Collins	Sandhill controlled burn study
Collins	Bottomland forest tornado study
McLeod	SRS timber compartment # 32 vegetation study
McLeod	SRS timber compartment #33 vegetation study
Sharitz	1987 study on photosynthesis and growth in *Sapium* seedlings
Sharitz	988 study on photosynthesis and growth in *Sapium* seedlings
Sharitz	Effects of flooding and root competition on bottomland species
Sharitz	Effects of root competition on seedlings
Sharitz	Early germination greenhouse study
Sharitz	HWCTR study on effects of flooding and root competition
Sharitz	HWCTR flooded seedling study
Sharitz	HWCTR shaded seedling study
Gibbons	Stinging trichome study
McArthur	Carolina bay nutrient and soil data
Brisbin	Uptake of ^{137}Cs by mallards
Brisbin	Alligator comparative ^{137}Cs measurement study
Mills	Petroleum degradation in soils
Jagoe	Tadpole predation by dragonfly larvae
Gibbons	Thermal biology of digestion in rubber boas
Gibbons	Body temperature variation in free-ranging rubber boas
Newman	Relative toxicity of metals to bacteria - Microtox II
Gibbons	Larval period duration in *Hyla squirella*
Meffe	Carolina bay fish populations
Pinder	Carolina bay hydrology study
Dixon	Forest canopy light penetration study
Hinton	Pond A sediment study
Smith	Cotton mice genetics study
Congdon	Oral deformities in tadpoles
Hinton	Par Pond sediment study
Sharitz	"Conner-Day" bottomland hardwood study

A.5 WILDLIFE STUDIES

Studies of Waterfowl Populations on the SRS

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

This program is designed to provide basic ecological information on both resident and migratory waterfowl populations inhabiting the SRS. In particular, studies within this program provide data on population demographics of breeding and wintering species of SRS waterfowl, wintering waterfowl species composition and distributions, and natural history traits related to survival and reproductive success. The data from this program have complemented contaminant fate and effects studies being conducted by the program "Radionuclide Cycling in Vertebrates Inhabiting Contaminated Wetlands" under the direction of the SREL Division of Biogeochemistry, by providing data such as quantitative waterfowl distributions 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 hunters who may consume such birds.

During the winter of 1995-96, field work was initiated at Par Pond as a part of a new study in which a Geographic Information System (GIS) approach will be used to spatially and temporally arrange and interpret biotic and abiotic data related to waterfowl at that reservoir. Data which have been collected and are to be stored as GIS coverages include: reservoir sediment and waterfowl food resource ^{137}Cs levels, waterfowl behavior data (eg., foraging rates), waterfowl whole-body and tissue-compartment ^{137}Cs levels, waterfowl food preference data, and waterfowl population distributions on the reservoir. The goal of this work will be to link the various data layers to model contaminant uptake within waterfowl populations utilizing Par Pond and to infer potential risks to human consumers of these waterfowl. A second field season of data collection is planned for the winter of 1996-97 at Par Pond.

Long-term studies of wood ducks, screech owls, and other species nesting in boxes placed in contaminated and uncontaminated SRS habitats continued in 1996. Since 1982, over 26,000 wood duck eggs have been laid in long-term monitored SRS nest boxes, and over 11,000 ducklings have hatched and occupied SRS wetlands. During 1996, wood duck incubation behavior data was collected from more than 60 nests, and will be used to identify behavior patterns that result in high nesting success and high future survival of breeding females. A manuscript was written that details the organic composition of wood duck eggs collected from the Pond B reservoir. These results indicate that nutrient provisioning to eggs as laying progresses may be an important factor allowing most waterfowl species to lay the relatively large clutches of eggs that they are capable of laying. In collaboration with the Wildlife Radioecology Program of the Division of Biogeochemistry, thirty new nest boxes were placed around L-Lake during early 1996. Wood duck eggs were collected from these L-Lake nest boxes as well as from those boxes on Par Pond and Pond B in 1996 to determine mercury contamination levels.

Waterfowl population ecology studies will likely continue to focus on the lower Steel Creek drainage and L-Lake, due to a proposal by DOE to drain that reservoir. In addition, future studies will continue to document sitewide waterfowl population numbers, their spatial distributions, and basic ecology, which are particularly relevant to the continued assessment of contaminant effects on

these waterfowl and risks to human consumers.

Genetic and Demographic Analysis of White-tailed Deer

M.H. Smith and R.K. Chesser

We are continuing to study the population ecology and population genetics of the SRS deer herd in the context of plant operations. The focus of our research has thus been threefold. First, to try and fill any gaps in our knowledge of the ecological and genetic responses of the SRS deer herd to plant operations. Second, to analyze the variation of ecological and genetic parameters in time and space for the SRS deer herd. Third, to place the SRS deer herd in the proper geographic and temporal context by extending 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.

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

Populations of organisms are not static in time or space, especially large, vagile vertebrates. The SRS deer herd provides a unique opportunity to study such changes because of the length of time for which the herd has been under study. A paper currently in review by The Journal of Heredity shows how correlations between genetic loci can exhibit a large range of variation, and this variation can be used to indicate periods when unique events may be impacting a species. In addition, we have completed an analysis of several years of data concerning car-deer accidents on the SRS. We have published one popular article and another technical article has been submitted. We are presently placing the car-deer accident locations into a GIS database in order to analyze the effects of land-use patterns on the SRS in relation to the frequency of accidents between automobiles and deer. We are also refining our ability to analyze the spatial components of other aspects of white-tailed deer management and ecology by cooperating with SRFS and other SREL researchers in a program to place deer hunt stand locations into a GIS database using currently available GPS technology.

The previous data cannot be reliably used to make inferences regarding the impacts of plant operations on the SRS deer herd until they are placed in the proper spatial and temporal context. A 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 has been expanded to include mini-satellite DNA analysis to provide finer scale resolution of spatial genetic patterns on the SRS. On this scale of resolution, the genetic structure of the SRS deer population does not appear to have been affected by plant operations. We have also pursued the use of white-tailed deer as an indicator species of

radiological effects on the SRS. Using a very sensitive modification of a standard RNAse protection assay, called a non-isotopic RNAse cleavage assay (NIRCA), mutation events can be detected in the DNA down to single base-pair modifications. Laboratory techniques have been perfected for this technique and quality-assurance runs comparing NIRCA results to DNA sequencing analysis has been performed. We also continue to refine our previously used techniques in light of current technology (Ratnaswamy *et al.* 1993)

The SRS deer herd is also being used as a unique example of a population that has been studied ecologically and genetically for an extended period of time (currently 30 years). This allows it to be used for extending both ecological theory and wildlife management practices. An invited paper for the journal *Forest Genetics* that reviews the implications of genetic heterogeneity for wildlife management and conservation biology is currently in press (Smith et al., *in press*). In this paper the SRS deer herd is used as the principal model for the application of ecological and genetic data in the management for wildlife species that maintain intimate contact with human society.

During the last year we have continued to gather data from the annual hunts. We have used our database 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 decisions for the SRS deer herd. We have also continued to make our data more accessible to other groups on site. We are currently assembling a unified database that will contain information from the deer hunts, genetic analyses, and HP monitoring activities as well as car-deer accidents and be accessible across the site-wide network.

Population Dynamics of Turtles

J.W. Gibbons

Knowledge of the basic ecology of turtles has been applicable to a variety of environmental issues of importance to DOE, and such studies continue both in DOE Set-Aside areas and other habitats on the SRS. SREL research on the population dynamics and ecology of freshwater turtles was initiated on the Savannah River Site in 1967 and have continued uninterrupted since that time. This research has subsequently become recognized nationally and internationally as one of the longest continuous field ecology studies on naturals species populations in the world. The studies have been important in determining basic ecological information on the demography, life history, and habits of freshwater turtles of North America in general and the Savannah River Site in particular.

The importance of peripheral terrestrial habitats has continued to be investigated this past year at the Dry Bay Set-Aside with the tracking of more than 200 semi-aquatic turtles onto land. Their behavior in response to the former clearcut area on the south side of the bay suggests that such habitat may be unfavorable for turtle hibernation sites several years after disturbance. We also have examined the nesting habits of the chicken turtle, which is a protected species in some parts of its range, in an effort to establish appropriate conservation guidelines for the species. Because turtles are excellent indicators of both radioactive and non-radioactive contamination as well as of landscape disruptions such as clearcutting, the acquisition of basic ecological data will serve as a foundation for assessing impacts on habitat alteration and certain forms of pollution to natural systems and should prove applicable to many of the environmental issues of concern to DOE on the SRS. Turtles will continue to serve as a biological monitor of radioactive and other contaminants and in the

determination of whether free-ranging wildlife can incur genetic damage from contaminated sites. The continued long-term survey and research of particular habitats permits natural population fluctuations and response to natural stresses to be revealed.

Amphibian and Reptile Ecology

J.W. Gibbons

The general objective of these studies is to acquire baseline information on the basic ecology, life history, and distribution patterns of all species of reptiles and amphibians known from the Savannah River Site. In-depth population studies are conducted on selected species whose abundance in particular locations make them tractable for this purpose. A general objective is to determine distributional patterns of all SRS species of herpetofauna on the site and to establish community composition of reptiles and amphibians at particular sites and habitats. The initial surveys for reptiles and amphibians on the Savannah River Site were made in the early 1950's when the area was first set aside for the production of nuclear materials. An additional survey was made in the mid-1960's by a University of Georgia graduate student at SREL. Since 1967, long-term records have been kept of the population status, distribution patterns, and general ecology of all species of reptiles and amphibians known from the site. The projects have resulted in the publication of more than 100 technical articles in scientific journals, the publication of two books that focus specifically on SRS species, and the preparation of numerous official reports for use by DOE. The long-term nature of the studies has resulted in the discovery of 20 species of reptiles and amphibians not reported to be present in Freeman's surveys in the 1950's and the finding of two species (the pine woods snake and Florida mud turtle) not known formerly from this region of South Carolina. The gopher tortoise was found on the SRS in 1996. The gopher tortoise is a federally protected species in some parts of its range. This finding indicate that, despite extensive research on the herpetofauna, sensitive species may be present that we are unaware of.

Turtle Population Dispersion

J.W. Gibbons

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

During the past year we continued to sample diamondback terrapins in the Kiawah River (control site) for analysis of contamination with of those from the lower Savannah River, which might reveal long-term accumulations of radioactive materials from the SRS. We expect to provide a sufficient comparison of the uptake of various chemical and radioactive contaminants between the control population of diamondback terrapins and those in the lower Savannah River. We have also continued to monitor all turtles captured on the SRS for radioactive contamination and during the

past year have continued to find free-ranging individuals that were significantly above background. Our intent is to examine the entire data set for the purpose of compiling a report on the history of radioactive turtles on the SRS.

Wildlife Studies of Vertebrates: Population Biological Effects of Environmental Perturbation

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

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

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

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A.6 AQUATIC COMMUNITIES OF RESERVOIRS AND PONDS

Aquatic Communities of Natural Wetland Ponds

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

The Carolina bays and other natural wetland ponds of the Savannah River Site support rich aquatic communities. During the past year, our research on the aquatic communities of these ponds has focussed on completion of a 12-year study on invertebrate production and dynamics at Rainbow Bay, completion of a 2-year study of invertebrate composition at Bay 93, development of population models, and analysis of biogeographic pattern revealed by survey studies.

Rainbow Bay. Our long-term study (1984-1995) at Rainbow Bay focused on the benthic and planktonic invertebrates that function as the main trophic link between primary producers and salamanders and other vertebrate consumers. The Rainbow Bay invertebrate studies, in conjunction with the amphibian studies conducted through the herpetology program, constitute the only comprehensive long-term data on animal populations in wetland ponds in the southeastern United States. Because the populations in these ponds are extremely responsive to interannual variation in hydrologic conditions, the ranges of "normal" or "typical" variation defined by these data provide an invaluable reference for interpreting results from surveys and manipulations on other wetland ponds.

The invertebrate assemblage at Rainbow Bay is dominated by oligochaete worms, chironomid midge larvae, and microcrustaceans. Because the community is trophically complex, strong control of community composition or dynamics by any class of predators seems unlikely. However, in years when populations of salamander larvae are unusually large, predation by the larvae may suppress populations of chironomids. We submitted a manuscript on dynamics and production of aquatic invertebrates to the journal *Freshwater Biology*, and have prepared a draft version of a manuscript on emergence of adult insects from this pond.

Bay 93. We completed a two-year (1994-1995) program of sampling for aquatic invertebrates at Bay 93, where an old ditch was plugged by the Savannah River Forest Station (SRFS) to restore the hydrology. A microcrustacean assemblage similar to that of nearby ponds, which had been sampled in earlier (1987, 1990) surveys, appeared in the first year of the treatment. Because our genetic studies on closely related species in other Carolina bays indicate that migration rates are extremely low, we hypothesize that the populations in Bay 93 developed from resting stages remaining in the sediments. We presented results of this work at a SREL/SRFS-sponsored workshop on bay restoration.

Population Models. To test and strengthen our understanding the dynamics of natural populations in wetland ponds, we have built computer-based population models, including a model for the marbled salamander, *Ambystoma opacum*. The salamander model was developed in collaboration with the herpetology program, and the work was partly supported by a contract from the Environmental Protection Agency to develop models for ecological risk assessment.

For pond-breeding amphibians, larval growth and survival are often density-dependent. Combined with delayed reproduction and high reproductive capacity, density-dependent controls can generate wide fluctuations in abundance, even in the absence of environmental variation. The paper

by Taylor and Scott (1997) analyzes stability and sensitivity of a model for the marbled salamander and establishes relationships between the simulation results and the analytic solutions to models for density-dependent growth. When survival in non-larval stages is high, equilibria are unstable, and high reproductive potential at low population densities leads to wide fluctuations in abundance. Generally, the model is more sensitive to variation in demographic parameters of the terrestrial (juvenile and adult) stages than of the aquatic (egg and larva) stages. We applied the model to data from the natural population of *Ambystoma opacum* at Ginger's Bay on the SRS. Annual recruitment of metamorphs at Ginger's Bay is low (0.7-7.9 metamorphs per breeding female over 9 yr), and the model demonstrates that either high terrestrial survival or immigration is required to maintain the breeding population.

Surveys. Our goal in a series of surveys of wetland ponds has been to characterize species composition of planktonic microcrustaceans and to test for associations between occurrences of species and geographic, environmental, and ecological factors. These surveys, in conjunction with our long-term studies of invertebrate dynamics, provide a baseline for defining typical modern assemblages in these habitats and for evaluating the success of manipulations, such as the hydrologic restoration conducted at Bay 93 and proposed for other Carolina bays. We submitted a manuscript to *Journal of Marine Systems* on the biogeography of calanoid copepods of both natural ponds and man-made reservoirs on the southeastern Coastal Plain.

Trophic Pathways in Reservoirs

B.E. Taylor

Decisions about remediation plans for these accidental release radioactive contaminants depend on reliable assessments of their environmental mobility. The experience and data from the Savannah River Site can be used to test and improve our understanding of the fate of radionuclides in lakes and reservoirs, both on the SRS and elsewhere.

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

Whether these imbalances are artifacts of statistical error or symptoms of conceptual error is unclear. I wrote a proposal (Taylor, Hinton, Dixon, and Håkonson) to obtain funding for further work, including application of uncertain analyses to a mass balance model, on this problem.

Environmental Histories (In Collaboration With Savannah River Archaeological Research Program)

B.E. Taylor and M.J. Brooks

The land that is now known as the SRS has sustained human occupation for more than ten thousand years, and its timber and soils have been intensively exploited for a century and a half. These activities have strongly influenced the modern conditions in many of the aquatic habitats on the SRS. To support management activities, as well as to characterize these habitats, we are investigating historic and prehistoric conditions in Carolina bays and their surroundings. This work has been focused on one hydrologically manipulated bay (Bay 93), six Set-Aside bays (Flamingo, Mona, Woodward, Sarracenia, and Thunder Bays, and Craig Pond), and one additional bay (Bay 58). This study complements and supports the Carolina bay studies in the Ecosystem Restoration and Remediation Program, providing information about historic influences on vegetation in and around the ponds as well as information on the ponds and their hydrologies.

Research on historic era land use revealed intensive agricultural activity as early as 1850 around all eight of the bays. Small amounts of sugarcane and rice were grown on the Bay 93 property in the mid-nineteenth century, but we have not yet determined whether they were grown in the bay. We presented these results at a SREL/SRFS-sponsored workshop on bay restoration.

At Flamingo Bay, analysis of archaeological and paleolimnological data indicates that morphology of the bay has changed: the sand margin of the eastern rim has been slowly building, and the basin has been slowly filling (Brooks, Taylor, and Grant, 1996). Much of the distinctive Carolina bay morphology may have actually evolved during the very late Pleistocene-early Holocene, around 12,000 to 10,000 Y.B.P. On the basis of shifts in human activity at Flamingo Bay, we hypothesize that hydrologic conditions similar to those of the modern pond, which dries completely every 5-10 years, may have been established as early as 4000 Y.B.P. Our results indicate that fluvial-centric models of terminal Pleistocene-early Holocene human adaptations on the South Atlantic Coastal Plain require substantial revision to include intensive human use of isolated upland ponds.

We have explored the use of siliceous microfossils, particularly diatom frustules, from pond sediments to infer past environmental conditions. Evelyn Gaiser, a doctoral candidate at University of Georgia, surveyed the diatom flora of modern ponds to determine correlates between diatom assemblages and environmental conditions. Certain taxa to respond strongly to pond hydroperiod. We have prepared a draft version of a manuscript on these assemblages and are using microfossil data from Flamingo Bay to test our hypothesis about the shift in hydrologic conditions in the pond.

Vegetation Development and Contaminant Uptake in Par Pond

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

Management strategies, such as the decision to refill Par Pond, the choice of input water, and the maintenance of stable or fluctuating hydrology, influence vegetation development and contaminant transport. To determine the influence of water source (Par Pond, Pond B, Savannah River) and hydrology (stable, fluctuating) on development of vegetation from the seedbank and on radiocesium transfers among sediments, macrophytes, and water, sediment cores were removed from the original waterline at 13 locations around Par Pond. Cores were placed in pots and given a water

source and hydrology treatment for one growing season. Plant species composition in the pots was censused at the end of the 1995 growing season. Plant samples and samples from pot sediments are being analyzed for radiocesium content. As well, sediment samples are being analyzed for nutrient content.

Recent publications: Aquatic communities of Reservoirs and Ponds

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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

The Savannah River Ecology Laboratory has continued it's commitment to being good stewards of the environment with regard to research and compliance activities. This past year the SREL participated in the Rock Hill Work Out Initiative, a site-wide effort to develop a "right-sized" monitoring program. This activity has an estimated cost savings of $11M to the Department of Energy for the entire SRS. SREL has also participated in several site committees that address environmental concerns: the Central Environmental Committee, the ISO 14000 Task Team, the Pesticide Use Task Group, the Waste Minimization/Pollution Prevention Committee, the Site Air Committee, and the NPDES Permit Review Group.

To ensure regulatory compliance with all laboratory activities, the SREL Environmental Program conducted 36 assessments in cooperation with the Department of Energy. SREL conducted three internal assessments on NPDES/Outfall compliance. Two environmental program reviews were also conducted in conjunction with WSRC/SRS activities. All observations associated with these assessments have been addressed and successfully implemented by the SREL Environmental Program Coordinator.

With SREL committed to continual improvement, annual performance evaluations of SREL personnel now include a measure of environmental performance. SREL is also programmatically committed to pollution prevention, waste minimization, ecolitter clean-up, and recycling on a voluntary basis.

Future considerations for SREL's environmental program will be addressed in the Lab's participation in DOE's Necessary and Sufficient process.

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 enhanced to further that goal.

The SREL Environmental Health and Safety (EH&S) Services 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 facility inspections and corrective actions were initiated through the SREL Work Order System. Monitoring of fume hoods, exposure to chemical, radiological, and physical agents, and safety apparatus was accomplished. Additionally, several fume hoods were upgraded, additional safety showers and eye washes were installed, the 737-A fire alarm system was enhanced, and ergonomic hazards were addressed through facility upgrades. The SREL Safety Manual, Project Safety Appraisal Forms, and Chemical Ordering were offered up as electronic on-line versions and access to MSDS's was made available through the World Wide Web. As a member of the SREL Facilities Committee, the EH&S Manager is consulted on new construction projects and major renovations. Plans for a new radiation lab, the Animal Care Facility, the Distance Learning Center, the greenhouse addition, and renovations to the receiving building and technical staff office building were reviewed. Safety inspections were conducted for the new receiving building, and the laboratory wing prior to acceptance from the construction contractor. SREL also formally implemented a hearing conservation program and revised its Safety Manual and Chemical Hygiene Plans. The EH&S program has been an active participant in SREL's Necessary and Sufficient process, providing information and input to the Convened Group and the Identification Team.

Lessons learned information, product safety alerts, hazard alerts, and training opportunity information continued to be disseminated over GroupWise (electronic mail system), in the Grapevine and Grapeleaf publications, and by posting information on the Safety Bulletin Board. Additionally, pamphlets and periodicals were made available, the safety lending library and resource room were upgraded, and safety information was placed in break rooms and the reception area.

Formalized training, which includes job-specific training for new personnel, has been enhanced. For those personnel who required it, training was provided in driver safety, forklift safety, hearing conservation, and boating safety. Radiation workers were trained under the SRS program with additional training at SREL in X-ray and sealed source safety. Training also was offered in first-aid and CPR, fire prevention, laboratory safety, back care, heat stress, personal protection, and ergonomics. A zoonosis seminar presented to SREL personnel was additionally presented to more than 50 SRS site personnel at the SREL conference center. A monthly safety video series was also presented this year. Courses in effective communication and effective management were promoted by EH&S Services.

DOE/SR and WSRC assessments in welding and cutting, compressed gas handling, electrical safety, OSHA compliance, fire safety, laser safety, safety-related record keeping, bloodborne pathogens, and confined space safety were conducted. Additionally, DOE/HQ conducted a general surveillance and assessments on industrial hygiene noise monitoring, fire protection, and safety-related record keeping. Overall, SREL received some of its best safety performance reviews this year. The

National Safety Council's administrative audit of SREL's EH&S program concluded that significant improvements had been made over the last three and one-half years. The audit team rated the SREL EH&S program at 8+ on a ten point scale, one of the highest ratings ever received by a university safety program.

SREL was presented the Unique and Innovative Award of Recognition from the National Safety Council for its driver improvement program which, over a three-year period, eliminated automobile accidents for newly hired (< 12 months) personnel and reduced the automobile accident rate for long-term personnel by over 65%. Overall injury rates for SREL personnel have exhibited a general downward trend over the past five years.

SREL EH&S Services was also invited to participate in this year's SRS Safety Conference and co-hosted (with the Medical College of Georgia) the annual meeting of the Southeastern University Radiation Safety Officers. The SREL Environmental Health and Safety Manager was invited to present a seminar on field work safety at the 1996 National Safety Council Congress and to participate on the Ames Laboratory Necessary and Sufficient Process Confirmation Team.

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 FY96. 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

SREL Wood Stork Program: Foraging and Breeding Ecology

A.L. Bryan, 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 1 through September 1 of 1995, and April 19 through July 31 of 1996. During the Fall surveys (1995), no storks were observed in the SRSS during 6 surveys. During the early Spring and Summer surveys (1996), no storks were observed in the SRSS area; however, several Carolina Bays (Peat and Sarracenia bays, Craig's Pond) and other temporally-isolated wetlands on the SRS were utilized by large numbers (>25) of storks.

Stork prey samples collected from several active (Carolina bays) and potential (reservoirs) foraging sites in 1995 were analyzed for the presence of mercury. As expected, prey-sized fish from the reservoirs frequently contained levels of mercury above the level of concern suggested (USFWS) for the diet of a "sensitive avian species." However, many prey-sized fish from Carolina bays on the SRS also contained mercury in (USFWS) levels of concern. Additional samples were collected in the summer of 1996 from active and potential foraging sites for future analyses.

We continue to monitor the breeding success of storks in the Birdsville and Chew Mill Pond colonies in Jenkins County, Georgia, since they are the closest (approximately 45 km) sources of storks that might forage on the SRS and the Kathwood foraging ponds. There were 189 stork nests in Birdsville this year, which produced an average of 1.9 ± 1.4 fledged young per nest. The number of nests is far lower than nest numbers from recent years (245 in 1995). The Chew Mill Pond colony, which first formed in 1993, contained 95 stork nests which produced approximately two fledged young per nest. This colony, which is thought to be a "satellite" colony of Birdsville, increased dramatically in size from previous years (45 nests in 1995). Another colony discovered in 1995 in Screven County, Georgia, 38 km SE of the SRS, did reform in 1996 with approximately 40 nests. We were not able to secure landowner permission to enter this property and, therefore, were not able to monitor reproductive success at this site.

The Kathwood Lake foraging ponds were made available to the storks on July 5, 1996 when pond 4 was lowered. Storks utilized the ponds for approximately 40 days, with a single day maximum of 238 storks observed in pond 4 on July 7, 1996. We continued our study of nocturnal foraging by storks, which showed that the birds forage at least as much at night as they do during the daylight or crepuscular hours. We also had an undergraduate intern studying the foraging interactions between Wood Storks and Great Egrets, which possibly compete for similar prey at Kathwood and other sites. Foraging behavior studies like this will assist in our determination of consumption rates of prey by 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 were also using the ponds. Last year a juvenile stork banded as a nestling (in 1995) at the Harris Neck National Wildlife Refuge below Savannah, Georgia, was observed foraging in pond 2 at Kathwood. This year, a different subadult (2 yr old) stork banded as a nestling in 1995 at the Harris Neck National Wildlife Refuge was

observed foraging at Kathwood.

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 July 22, 1996. Participants included visiting Better Education for Students and Teacher/Oak Ridge Institute for Science and Education teachers and educators from the SRS education/outreach program. This workshop, which will likely become an annual event, allows the participants to become involved in hands-on research/monitoring while learning about stork ecology and the successful mitigation program at Kathwood. A teacher-intern also worked at Kathwood during 1996, acquiring field experience (fish sampling, bird monitoring, behavioral observations) to take back to the classroom as well as producing a brochure describing the facility.

The SREL Wood Stork Program, in cooperation with Georgia Department of Natural Resources, received funding from the U.S. Fish and Wildlife Service to inventory wading bird colonies in the Georgia coastal plain. Data analyses are on-going.

Recent Publications

Bryan, A.L. Jr. 1996. The SREL Wood Stork Program: 1995 Annual Report. Unpublished report to DOE.

Bryan, A.L. Jr. 1996. The foraging ecology of Wood Storks nesting in the coastal zone of Georgia and South Carolina in 1995. A Report submitted in fulfillment of a US Fish and Wildlife Service Section 6 Grant to the Department of Natural Resources.

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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.A. Ott, 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 became operational in FY-1996; the next four years will allow SREL to complete the post-construction phase of the study. Current research emphasizes: 1) monitoring the water quality of peripheral streams that were impacted by DWPF construction, 2) understanding the population dynamics of amphibian species so that human-induced changes can be separated from naturally occurring population fluctuations, and 3) studying the role of terrestrial buffer zones around wetlands in maintaining the viability of wetlands biota.

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

When DWPF was built, an entire Carolina bay (Sun Bay) was eliminated. Carolina bays are important centers 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. Recent analyses indicate that population sizes of four amphibian species have declined at Rainbow Bay over the last 18 years, whereas numbers of one species have increased. SREL research indicates that these changes most likely are natural fluctuations related to climatic variation, predation, competition, and other natural interacting factors. Data from Rainbow Bay represent the longest ongoing multispecies study of amphibian populations in the world. In spite of this, statistical power analyses developed during FY96 indicate that additional data are needed to adequately assess long-term trends, due to the high natural variability in population sizes.

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

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

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Pechmann, J.H.K. 1995. Use of large field enclosures to study the terrestrial ecology of pond-breeding amphibians. Herpetologica 51: 434-450.

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Semlitsch, R.D., D.E. Scott, J.H.K. Pechmann, and J.W. Gibbons. 1996. 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).

Taylor, B.E. and D.E. Scott. 1996. Effects of larval density-dependence on population dynamics of *Ambystoma opacum*. Herpetologica (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 and (3) the sub-lethal effect of coal ash basin toxicants on organisms. 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, in South Carolina, and throughout the Atlantic Slope. This broad effort is necessary to properly evaluate the status of local species. We have applied DNA techniques to propose a phylogenetic hypothesis for the family Unionidae and to use this to evaluate relationships among species. We have also applied allozymes and DNA sequencing data to address genetic differentiation in two rare mussels. The results have been used by USFWS to determine conservation needs for these species. Additionally, studies have suggested that the nomenclature used for freshwater mussels on the Atlantic Slope is in need of revision. We have found that cryptic species have been overlooked (e.g., *Elliptio hepatica* of the Upper Three Runs system). Species names have been misapplied (e.g., *Elliptio producta* of the Savannah River (type locality), has little resemblance to *Elliptio* to which this name has been applied in Virginia). Conservation efforts directed toward these rare species will be greatly enhanced by population genetic studies to determine genetic diversity within and among populations and to delineate species boundaries.

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D.2 FISH

Ecological Risk Assessment and Stream Restoration due 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 sites impacted by past thermal effluents and current flow augmentation, 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 and has continued to the present. To date, seven seasonal samples have been taken, and an eighth is in progress. Sites were chosen to include major habitat types in the selected reaches of each stream. In January 1996, the number of sample sites distributed among these four streams increased from the original 48 to 55 as a result of preliminary analyses. Surveys consist of multiple-pass electroshocking, identification and counting of collected individuals of all species, measurement of individuals of most species, and return of fish alive to the stream. To date, over 50,000 fish have been collected. 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 55 sites, at least five permanent habitat transects have been established, upon which detailed information is collected, including channel dimensions, depth profiles, channel erosion and sedimentation patterns, substrate types and firmness, presence and type of woody debris, presence of submergent and emergent aquatic vegetation, canopy cover (amount and type), water velocity, pH, conductivity, and dissolved oxygen. Our constant elevation markers will help determine stream bed scouring and sediment deposition over time. Sediment loads in the water columns of each stream during flood events also may 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, impacted streams are heavily dominated by a few groups of fishes, including suckers, mosquitofishes, minnows, and sunfishes, which are characteristic of disturbed areas. Control streams have a more even distribution of species, characteristic of 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-seven of the 55 study sites are distributed among these control and experimental sections of Pen Branch, and allow analysis of the effects of restoration efforts on the fish communities and the system. Data that had been collected prior to vegetation manipulation have established a baseline of fish communities before experimental restoration, and data from undisturbed streams are serving as a target endpoint of a successful restoration. Our current data collection is monitoring the short-term effects of the restoration process as well as establishing an early trajectory of the recovery process. Preliminary analysis indicates that removal of the low willow/shrub canopy has greatly increased aquatic macrophyte and fish abundance in the restoration areas. Long-term monitoring will be required to record the ultimate effectiveness of the restoration efforts.

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

- Interspecific spawning interactions and demography of selected species: We have learned that dusky shiners migrate into slow, still waters to spawn on nests of redbreast sunfish , 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 four 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; 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; and d) mating systems of redbreast sunfish are being examined using microsatellite DNA in collaboration with Dr. John Avise of the University of Georgia. All of these studies began in 1995 and are in progress.

Physiological Responses. Monthly collections of dusky shiners were made in the four streams to study their growth, lipid storage, and size and reproductive patterns as a function of the systems in which they occur. Samples are being 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 are 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 a indicator that can be used to make decisions regarding remediation options in the Par Pond system.

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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 electricity and steam 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 continued 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 and selenium, had severe deformations of the mouth, and had higher resting metabolic rates (measured as O_2 consumption) when compared to reference animals. We transplanted eggs of the bullfrog into the ash basins and into an unpolluted reference pond and found that deformities and above-normal metabolic rates were induced by conditions in the ash basins. Thus, there is some feature to the ash basins, possibly the mixture of trace elements in sediment and water, that is causing substantial impacts on the energy budgets of bullfrogs. Energy budgets are being impacted in at least two ways. First, acquisition of some resources appears to be limited due to oral deformities. When presented with natural algal food in a laboratory experiment, tadpoles with mouth deformations grew significantly more slowly than those with normal mouths, probably due to inefficient feeding by the former. Second, increased metabolic rates indicate that tadpoles raised in the ash basins must spend a much greater amount of energy simply to sustain life ("maintenance costs") than do tadpoles raised in unpolluted areas. Modified acquisition of resources and maintenance costs probably decreases the total amount of energy that bullfrogs have for other processes such as growth, storage, and reproduction, therefore potentially affecting population dynamics.

Recent work has also been directed at identifying effects of exposure to coal ash pollution on behavior and swimming performance in bullfrog tadpoles. We have found that tadpoles collected from the ash basins have about a 50 % reduction in sprint speed and sustained speed when compared to those collected from unpolluted sites. Since swimming speed might influence the ability of the tadpoles to avoid predators, we conducted an experiment in which tadpoles transplanted as eggs into

the ash basins and a reference pond were placed together in outdoor tanks containing predatory juvenile snapping turtles. In tanks that contained a predator, tadpoles raised in the ash basins had much higher mortality than did those raised in the reference pond. When predators were absent, survival was equal for tadpoles from both sites. We are currently testing the hypothesis that high levels of selenium present in collagen proteins in the tails in some way modify muscle performance.

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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, and A. Chlopecka

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 analyzed 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.

Another project was begun at the Columbia Metropolitan Airport, using a 7 ha barrow pit. This reclamation project was precipitated by massive sedimentation of a nearby road from the borrow pit runoff, posing traffic hazards. The eroding barrow pit is largely non-vegetated due to infertile soil conditions. The project was initiated as a multigroup activity between industry, the Soil Conservation Service, SREL, and SC DHEC. This reclamation project consists of two parts --- an experimental plot where treatments included various application rates of fly ash and chicken manure, either singly or in combination, and the rest of the area as a demonstration to indicate the potential significance of the fly ash as a soil quality enhancer. Plot treatments included fly ash rates up to 10 centimeter of surface material and chicken manure rates to provide 180 kg/ha 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 formulating regulations relative to this waste by-product for agricultural lands and physically degraded areas.

Recent Publications: Cycling of Coal/Fossil Fuel Contaminants

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

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Chlopecka, A. 1996. Forms of Cd, Cu, Pb, and Zn in soil and their uptake by cereal crops when applied jointly as carbonates. Water, Air, and Soil Pollution 87:297-309.

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E.2 RADIONUCLIDE CYCLING IN POND B

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

I. L. Brisbin, Jr.

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

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

With the completion of the refill of the Par Pond reservoir, follow-up studies have been undertaken to evaluate long-term changes in ^{137}Cs contamination levels of waterfowl using this site before, during and after reservoir drawdown. An unexpectedly high increase in contamination levels of this isotope in American coots prompted more detailed studies of the behavior and dietary habits of these birds during and after the drawdown period. Game-farm mallard ducks were also released on the reservoir following refill to continue studies of the availability of ^{137}Cs in the exposed and now reflooded mudflats of the Par Pond CERCLA operable unit. Cesium-137 availability on these exposed mudflats was evaluated during drawdown through studies of free-ranging bantam chickens at the same location where the mallard duck studies were subsequently undertaken.

Several major studies have now also been completed comparing the long-term patterns of decline of ^{137}Cs in three species of fish inhabiting the Pond B reservoir. Data from bullhead catfish, mosquitofish, and large-mouthed bass have confirmed that in most cases, the decline in ^{137}Cs body burdens is much more prolonged than would be predicted on the basis of the physiological turnover rate of this isotope in the fish themselves. These long-term declines rather seem to be related to the ecological conditions prevalent in lotic aquatic systems such as this impounded reservoir. These findings are producing important information for the prediction of long-term time courses of radionuclide contamination declines in the biota of the former reactor cooling reservoirs of the SRS,

in which radionuclide contaminant sequestration will continue for many years to come.

Similar studies of alligators resident in the Par Pond reservoir and L-Lake are now also documenting long-term changes in the ^{137}Cs contamination levels of this species as well. Future studies will emphasize the relationship of radionuclide body burdens in fish, waterfowl and particularly alligators to any evidence of genotoxological damage (e.g., DNA sequence alteration) that may be discovered in these animals. This will be accomplished through a close coordination of the work in this program with other SREL studies of the same species in the area of toxicology and risk assessment. Analyses of the long-term ^{137}Cs data base for over 30,000 white-tailed deer taken by hunters during the annual SRS fall hunts will also be undertaken. These studies of ^{137}Cs in deer will involve analyses using the Geographic Information System (GIS) to describe and predict spatial patterns of decline of this contaminant in deer as well as smaller game animals such as foxes and other furbearers. All of these species will be related to the same GIS spatial data base which is now being developed for the deer ^{137}Cs studies.

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

Recent Reprints

Colwell, S.V., R.A. Kennamer, and I.L. Brisbin, Jr. 1996. Radiocesium patterns in wood duck eggs and nesting females in a contaminated reservoir. Journal of Wildlife Management 60:186-194.

Peters, E.L. and I.L. Brisbin, Jr. 1996. Environmental influences on the ^{137}Cs kinetics of the yellow-bellied turtle (*Trachemys scripta*). Ecological Monographs 66:115-136.

Peters, E. L., I. L. Brisbin, Jr., and R. A Kennamer. 1995. Alternative agriculture as a substitute for environmental remediation. P. 523-537. *In:* Proceedings of an International Symposium on Environmental Impact of Radioactive Releases: Organized by the International Atomic Energy Agency. Vienna, Austria.

Pinder, J.E., III, J.W. Bowling, R.L. Lide, and L.M. Beatty. 1995. The distribution of ^{137}Cs in sediments of the littoral zone of a former reactor cooling pond. Journal of Environmental Radioactivity 28:57-71.

E.3 SOIL/SUBSURFACE REMEDIATION

In situ Remediation Techniques for Contaminated Soils

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

This program was created by redirecting funds from the old Biobarrier Program and more recently, 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 treatments involving the soil cover technique produced concentration ratios that were at or below the National Council on Radiological Protection 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 are now under preparation for publication, 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. 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 mitigating metal uptake, and because lime is fairly abundant and much cheaper than the other materials, it may be the ameliorant of choice. Results are now in press for publication in *Environmental Science and Technology*. This study is now being expanded, investigating additional ameliorants on soils singly contaminated by heavy metals.

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 performance evaluation of *insitu* 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.

Petroleum hydrocarbons are among the most prevalent soil contaminants at Department of Energy sites. At the Savannah River Site, hydrocarbon contamination has resulted from the use of various petroleum fuels (e.g., kerosene, gasoline, diesel fuel) and lubricating oils (e.g., machine oil, crankcase oil). Although several strategies are likely to be employed in the restoration of petroleum

contaminated soils, bioremediation is generally the preferred approach. The weathering of petroleum hydrocarbons in the soil environment is the sum of biological, physical and chemical processes. It is often difficult to clearly discern microbial from abiotic contributions to the overall process. This is of particular concern in assessing the effectiveness of different strategies in an *in situ* bioremediation plan.

Straight-chained hydrocarbons are biodegraded faster than branched-chained hydrocarbons which in turn are degraded faster than alicyclic compounds. With aromatic components, it is generally observed that the rate of microbial degradation decreases with increasing number of rings and the alkyl-substituted derivatives are degraded at a slower rate than the parent compounds. These observations have led to the concept that a selected compound, or a ratio of selected compounds can be used as an index of biodegradation.

Previous work conducted in our laboratory has identified isoprenoid (e.g., pristane and phytane) and dicyclic, diterpenoid hydrocarbons in soil samples collected from a diesel contaminant plume on the SRS. By monitoring these compounds or ratios of n-alkanes to isoprenoid compounds (e.g., nC_{17}/pristane) it should be possible to estimate the biodegradation of hydrocarbons over time. This study was conducted to determine if the relative change in compound concentrations or the ratios of specific molecular markers can be used to calculate the biodegradation of petroleum hydrocarbons in diesel fuel contaminated soil.

The study was conducted using soil microcosms maintained outside, under cover, allowing for temperature fluctuations and gaseous exchange. Moisture levels were maintained at 60% field water-holding capacity and were monitored and adjusted weekly. The contaminated soil was obtained from an underground storage tank area on the SRS.

Three microcosms were destructively sampled on days 0, 1, 2, 4, 8, 14, 33, and 64 of the study. The soil was processed using EPA method 3550 (amended) (1) which employed sonication extraction and solvent exchange. Total extractable petroleum hydrocarbons (TEPH), including marker compounds, were quantified using high-resolution gas chromatography and gas chromatography-mass spectrometry. Microbial biomass carbon (biomass-C) was also measured on each sampling date. The biomass-C analyses were performed on aliquots of soil from each microcosm using the chloroform-fumigation incubation method (2). Carbon dioxide for microbial biomass-C measurements was measured on a total carbon analyzer.

The fraction of the isoprenoid pristane and phytane remaining on day 33 of the study was significantly less than the other isoprenoid marker compounds (norpristane, farnesane, and the sum of the diterpenoids). However, during the same period, pristane and phytane were significantly more degraded than nC_{17} and nC_{18}. Concentrations of pristane and phytane differed significantly from those of the diterpenoids hydrocarbons at the completion of the study (64 days). Comparing the degradation of pristane and phytane to the straight-chained alkanes nC_{17} and nC_{18} showed a similar trend.

Pristane and phytane concentrations were significantly correlated with TEPH and biomass-C. However, the degree and rate of degradation varied among compounds. The differences in the concentrations of pristane and phytane on day 33 of the experiment relative to other measured hydrocarbon components provide qualitative evidence of the microbial degradation of the diesel fuel.

Ratios of n-alkanes to marker compounds (i.e., nC_{17}/pristane, nC_{18}/phytane, etc.) did not adequately describe TEPH degradation, and therefore cannot be used as a quantitative index for the

diesel fuel examined. The observed correlations between pristane and phytane concentrations with TEPH during the course of the experiment suggest that these values may be useful predictors of TEPH degradation. Further work is required to refine these relationships and validate their use in a variety of matrices and in mixed waste situations.

Recent Publications: Soil/Subsurface Remediation

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Adriano, D.C., A. Chlopecka, and D. Kaplan. Role of soil chemistry in soil remediation and ecosystem conservation. Soil Science Society of America Monograph (in press).

Adriano, D.C., and A. Chlopecka. Role of soil chemistry in soil remediation and sustaining ecosystem health. *In*: Soil Chemistry and Ecosystem health. (Ed.) P.M. Huaug. Soil Science Society of America. Madison, WI (in press).

Adriano, D.C., A. Chlopecka, and D. Kaplan. Soil contamination and remediation: Philosophy, Science and Technology. In Proceedings of International. Conference on Biogeochemistry of Trace Elements. (Paris, France) (in press).

Chlopecka, A. and D.C. Adriano. Mimicked *in situ* stabilization of metals in a cropped soil: chemical forms and bioavailibility of zinc. Environmental Sciences and Technology (in press).

Dudka, S. and D.C. Adriano. Environmental impacts of mining and smelting metal ores. Journal of Environmental Quality (in press).

Frankenberger, W.T., M.A. Tabatabai, D.C. Adriano, and H.E. Doner. Bromine, chlorine, and fluorine. In: Methods of Soil Analysis II. Chemical and Microbiological Properties. (ed.) D.L. Sparks 3rd ed. American Society of Agronomy, Madison, WI (in press).

Iskander, I.K. and D.C. Arriano, (eds.) Biogeochemistry of Trace Metal 2. Advances in Environmental Science. Science Reviews Ltd., Londa, UK (in press).

Martin, H.W., T.R. Young, D.I. Kaplan, L. Simon, and D.C. Adriano. Evaluation of three herbaceous index plant species for bioavailability of soil cadmium, chromium, nickel, and vanadium. Plant and Soil (in press).

Martin, H. and G. Sick. 1995. American beautyberry for borrow pit reclamation in South Carolina. Restoration and Management Notes.

Simon, L., H.W. Martin, and D.C. Adriano. Chicory (*Chichorium Intybus* L.) and dandelion (*Taraxacum officinale* web.) A phytoindicator of cadmium contamination Water, Air and Soil Pollution (in press).

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 fish species common on the SRS, the channel catfish (*Ictalurus punctatus*) and largemouth bass (*Micropterus salmoides*). Clearance volume-based pharmacokinetic models for ^{137}Cs, Cd, Hg, Rb, and Zn in catfish have been fit and manuscripts were submitted 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.

Studies 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 accepted for publication. The book *Quantitative Methods in Aquatic Ecotoxicology*, by M.C. Newman, described and compared ERA-associated methods.

Education/Training. A short course, *Quantitative Methods in Ecotoxicology*, was first

taught in FY95 and again in August 1996. A book. *Ecotoxicology: A Hierarchical Treatment* describing the results of the Second Savannah River Symposium was published. A workshop, *Quantitative Risk Assessment*, was held in August 1996 and chapters are being compiled into a book.

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

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Mulvey, M., M.C. Newman and A.N. Beeby. 1996. Genetic and conchological comparison of snails (*Helix aspersa*) differing in shell deposition of lead. . Journal of Molluscan Studies. 62:213-233.

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Newman, Michael C. 1995. Quantitative Methods in Aquatic Ecotoxicology. CRC Press, Boca Raton, FL. 426 p.426 (in press).

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F. ENVIRONMENTAL TRANSPORT PROCESSES

This research documents the environmental transport of contaminants in surface and subsurface environments on the SRS. The program also examines the impact chemical speciation and molecular mechanisms have on bioavailability and toxicity of metals.

F. ENVIRONMENTAL TRANSPORT PROCESSES

Distribution and Chemical Speciation of Metals and Metalloids in Biota Collected From Contaminated Environments by Spatially Resolved XRF, XANES, and EXAFS

P.M. Bertsch and D.B. Hunter

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 at regulating contaminant behavior. Additionally, investigations focused on molecular mechanisms of contaminant toxicity are underway to help elucidate the role of chemical speciation of contaminants on toxicity and of genetically controlled differences in important biological barriers associated with metal tolerance mechanisms.

A major obstacle in developing realistic environmental risk assessment or in designing environmentally sound, yet cost effective chemical and biological remediation strategies has been the ability to characterize the chemical speciation of contaminant metals and metalloids in complex environmental samples, free of artifacts introduced by indirect chemical extraction or sample preparation. Heterogeneous distribution of contaminants within environmental samples has further hampered unambiguous molecular characterization of the contaminants using conventional speciation techniques. Recently there has been considerable interest in using indigenous organisms as biomonitors to evaluate the extent of contamination and the efficacy of environmental remediation and restoration activities and for bioremediation of contaminated sites. Although most applications utilizing indigenous organisms as biomonitors have focused on acute toxicity, actual measurement of metals and metalloids in biota is a much more sensitive indicator of bioaccumulation that may be better related to potential chronic toxicity and more indicative of the relative performance of an environmental restoration strategy. There are a number of organisms that can function as effective biomonitors and as bioremediators as a result of their tendency to bioaccumulate or hyperaccumulate contaminants. Turtles are very attractive indicator species of metal contamination because they are extremely long-lived organisms, appear to be relatively tolerant to a range of pollutants, and because their shell is comprised of bone (apatite), which is a well known target organ for a number of transition and heavier elements. Turtle shells also exhibit growth annuli within which periodic growth deposition bands are discernible, thus providing the potential to examine and reconstruct historical information on contaminant exposure and/or accumulation by synchrotron-based spatially resolved X-ray techniques, including X-ray fluorescence (XRF), X-ray absorption near edge structure (XANES), and extended X-ray absorption fine structure (EXAFS) spectroscopies.

Significant quantities of uranium (~43,545 kg) and other metals (e.g, Ni, Cd, Cr, Cu) were released over 20 years as a result of fuel fabrication operations in M-Area on the Savannah River Site, with much of this being deposited in the Steed Pond system. Examination of shell fragments from turtles collected from Steed Pond by XRF collected at a 10 μm scale revealed that each of the major

contaminant metals were bioaccumulated and deposited in the bone, whereas no evidence for these metals were evident for the control samples. All metals were localized in the bone tissue to varying degrees, suggesting some time dependent pattern in metal uptake and deposition. Much greater concentrations of Ni compared to U were present in all samples examined, indicating a difference in the relative bioavailability of these metals, as they were present in approximately equal concentrations within the sediments. Regions resembling inclusions ~100 μm across could be observed visually by the petrographic microscope assembly and these regions were always found to be highly enriched in Ni. Other localized regions of contaminant deposition could be delineated at smaller spatial scales of between ~10v and 50 μm. Contaminant metals were also found localized in the ~50v to100 μm bands associated with the keratin-based epithelial layer of the shells.

Shell fragments from turtles collected in the wetland receiving outfall from a coal combustion by-product (fly ash) basin in D-Area were elevated in a number of metals and metalloids typically associated with coal and its waste products. These data demonstrate an amplification of the environmental signal, as deposition of these contaminants in the bone tissue at relatively high concentrations occurs in an environment of relatively low concentrations in the aqueous phase. Similar to the Steed Pond samples, the shell fragments demonstrated a localization of metals and metalloids in distinct regions within the bone and in the bands associated with the keratin coating.

Contaminant association with the keratin could conceivably result from surface sorption to functional groups associated with the protein or *via* physiological incorporation of bioaccumulated metals and metalloids. XANES spectra generated in regions of elevated Se concentration within the keratin of a bone fragment of a turtle collected from the wetland receiving flyash basin outfall demonstrate a coordination environment quite different than selenate [Se (VI)], the predominant soluble species in the basin water. A typical XANES spectrum collected on a Se rich region within the epithelial layer and spectra for the selenate and Se-methionine standards suggest that the Se exists predominantly in a coordination environment resembling Se-substituted methionine (Se-II), a functional group generally associated with sulfur containing structural proteins. Preliminary EXAFS data collected on the keratin indicates some evidence for Se backscatter, suggesting that some of the Se in the keratin exists in environments having di-selenide linkages (Se substituted cystine type amino acid functional groups).

These data unequivocally demonstrate that the Se associated with the epithelial layer has been bioaccumulated and metabolically incorporated into the protein structures. The combined use of noninvasive synchrotron-based XRF, XANES, and EXAFS to examine biota collected from contaminated environs at the SRS has demonstrated the utility of these techniques to provide information on contaminant exposure histories and relative bioavailability. This information could be quite valuable in environmental risk assessment activities and in long term evaluation of the efficacy of environmental remediation and restoration activities on the SRS.

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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

Evaluating Hyperspectral Remote Sensing Data for the Identification and Mapping of Forest Resources

J.E. Pinder III

A principal objective of SREL's work in ecosystem management is the development of enhanced applications or new interpretations of remote sensing technologies that can be used to assess ecosystem management activities on the SRS and other similar lands in public and private ownership. Part of this program involves tests and demonstrations of developing technologies in measuring forest composition and mapping forest resources. One of the more promising technologies for these purposes is the development of airborne hyperspectral scanners. These are aircraft mounted scanners that can measure reflectance in bands of only several nanometers wide on < 1-m x 1-m areas termed pixels. The resolution of these scanners represents a major advancement in both spectral and spatial resolution over current satellite-based sensors that normally use 100 nanometer bands and 20-m x 20-m pixels. Because of the enhanced spectral resolution, hyperspectral data has a greater ability to identify individual tree species or genera. Current satellite sensors can only recognize broad groups of species with generally similar colors and morphology. The greater spatial resolution suggests that hyperspectral data can be used to rapidly map individual trees and thereby inventory forest resources and assess biodiversity.

Although hyperspectral data have potentially great advantages over satellite data, most tests and demonstrations of the utility of hyperspectral data have been limited to laboratory examples or small-scale tests of agricultural plots. Few demonstrations and tests have been performed using large-scale expanses of natural or semi-natural vegetation. The purpose of this program, which is being conducted in cooperation with M. Pendergast of SRTC, is to perform such tests using hyperspectral data collected by an airborne TRW sensor on the SRS. The TRW sensor collects ninety 4-nanometer wide bands of reflected light from a minimum wave length of approximately 460 nanometers to a maximum of 890 nanometers. The pixel size depends upon aircraft elevation but is generally < 1-m for most SRS data acquisitions.

The project tests the ability of TRW hyperspectral data to identify tree species and measure the size of individual tree canopies in a 400m long by 40m wide transect that covers a complex moisture and elevation gradient in the Upper Three Runs watershed. There are numerous tree species that are intermixed across this gradient including loblolly pine (*Pinus taeda*), shortleaf pine (*Pinus echinata*), laurel oak (*Quercus hemisphaerica*), water oak (*Quercus nigra*), sweetgum (*Liquidamber styraciflua*), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*) and the successful identification of the individual species would be a clear demonstration of the usefulness of this technology for the rapid identification and quantification of forest structure.

Forest structure in the transect was measured by mapping trees from ground-based position measures. Trees were identified to species and their heights were measured. Height data is an important measure as relative tree height can affect reflectance patterns with shorter trees being obscured in the shadows of their taller neighbors. The extent of tree canopies for individual trees were mapped. These measures are required because the area covered by a tree canopy is an effective

measure of tree size and wood volume, and the ability of hyperspectral data to accurately measure canopy area and thereby tree size, is an important aspect of evaluating forest structure and forest resources.

The 90 bands of hyperspectral data were initially evaluated for data quality and data independence among bands. The data were also rectified to geographical coordinates measured to 1-m accuracy using Global Positioning Systems for landmarks within the transect. This rectification was necessary so that reflectance measured for 1-m by 1-m pixels in the hyperspectral data could be equated to tree positions on the ground surface. After initial data inspection, ten bands were selected for further analysis. These bands were selected based on their measurement of chemical or structural properties of leaves. The bands included the following wavelengths: 477, 549, 607, 674, 693, 713, 722, 761, 833 and 852 nanometers.

Data from these bands were subjected to a number of analytical procedures to identify tree species and tree canopies. These included supervised classification procedures based on matching reflectance patterns for trees to representative spectral signatures for the most common species and unsupervised classification procedures where multivariate statistical analyses attempt to combine reflectances into commonly occurring patterns that may then be interpreted as either individual species or groups of similar species.

Initial results indicate that hyperspectral data have a clearly superior capability of identifying tree types than that for satellite data; however, the identification of individual tree species is still not possible with these data. The hyperspectral data show clear separation of some tree genera, but species within the same genera are not readily separable. The success in mapping tree canopies is variable and depends on the spatial mix of tree species and the shape of the tree canopies.

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 been definitely 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 pollution.

Fire and Sandhills Vegetation

B.S. Collins and S. Fore'

Fire has formed the sandhills vegetation. With fire suppression, plant composition is slowly shifting toward an oak-dominated forest. This is a slow process and a process which can be reversed by the reintroduction of fire. Over the past decade, fire has been reintroduced into several stands and these stands sampled over time to describe the response of the vegetation. In general, 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 also less clumped following burning. Recently, several of these plots which had been initially burnt in the early 1980's have been reburnt to test additional hypotheses regarding the vegetational response. These plots are then resampled on a fixed schedule preceding the fire and the first, third seventh and eleventh year following fire. Several plots (winter burned and no burn) were resampled in the past year according to this schedule. Sampling effort in these permanent plots will decrease now for several years until the seventh year post fire.

The sandhills seedbank is sparse, and burning on fertilized seedbank samples did not recruit new vegetation from the seedbank. However, grasses common to the sandhills have >50% germination when not water limited. These results suggest that seed density, not germinability, limit regeneration in the sandhills.

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

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

Endangered Species

P. M. Dixon

The endangered species component of the ecosystem management program seeks to understand the demography and life history of rare plants on the Savannah River Site, and thus inform management decisions. The primary concern is with *Echinaceae laevigata* (smooth purple coneflower), a federally endangered species. Two populations of this species on the Savannah River Site are censused annually in the early fall. The larger population (Road B-5) currently has two sub-populations with a total of 609 plants and 851 stems. These are increases of 1.5% and 15%,

respectively, since fall 1994. There were decline of 33% (plants) and 40% (stems) in the portion of the population accidentally exposed to herbicides in spring 1995. No signs of herbicide burn on leaves were found, but plants marked in 1994 were not relocated in fall 1995. Experience with Burma Road population suggests that the observed declines may be overestimates because some individuals may persist underground. The Burma Road population continues to decline, and in the fall of 1995 contained only 146 plants. Continued annual monitoring of this site to document population trends is planned for this year. Comparison of the demographic parameters of the two populations, including the frequency of individuals resprouting after 1 or more years of aboveground absence, may suggest better management practices.

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G.2 FAUNAL DIVERSITY

Herpetofaunal Biodiversity Studies on the SRS

J.W. Gibbons

The southeastern region of the United States has the highest overall biodiversity of reptiles and amphibians in North America, and more research on herpetofauna has been conducted on the SRS than any other site in the country. Research to assess the reality of global climate change in response to anthropogenic effects is in progress on a worldwide basis. One important measure is biodiversity because the numbers and relative abundances of species inhabiting an area are a consequence of a variety of historical and current environmental factors, and biodiversity can be an indicator of human-caused effects if natural fluctuations in biodiversity can be determined. In an attempt to take advantage of the long-term herpetofaunal research programs on the SRS, analyses was completed during the past year for a major manuscript on the SRS as a model for determining herpetofaunal biodiversity. The effort involved data management and analysis of more than one million captures of reptiles and amphibians during the past 40 years. The paper is now in press in *Environmental Management* and should serve as a guide to sampling protocols and interpretation of survey records for other DOE sites and other government agencies. We have also continued to census herpetofaunal diversity through the use of drift fences with pitfall traps, coverboards arrays set in a variety of habitats (including Set-Aside areas), and a variety of other standard herpetological techniques. The herpetofaunal biodiversity studies will provide a solid foundation on which to assess a variety of impact issues, such as forest management and cleanup programs.

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

G.K. Meffe

The 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 were collected for three taxonomic groups: fishes, aquatic plants, and birds. Species distributions and abundances relative to present and former beaver dams were determined and associated data on habitat structural changes induced by beaver activities were 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 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. All fish studies were completed this year and three manuscripts were prepared and submitted for publication. Aquatic plant studies were completed last year and a manuscript for publication is now in review.

The bird surveys were completed this year and are being readied for publication. Like fishes and aquatic plants, bird communities are affected by the presence of beaver ponds, with some species found mostly or exclusively at pond sites.

Fish Species Diversity patterns Across a Carolina bay landscape. Sixty-three Carolina bays were surveyed in the summer of 1994, 1995, and 1996 for presence of fish, using baited minnow traps and hoop nets. The 1996 sample also included amphibians and reptiles, and a summary of collections is presented in Table 1. Environmental data, including temperature, pH, redox potential, distance to nearest permanent or intermittent aquatic habitat, elevation of the bay, and elevation of nearest aquatic habitat were also 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 published (Snodgrass et al. 1996).

Type of Animal Collected	#Species Collected	Total # Collected
Fishes	18	2,677
Amphibians	12	145
Snakes	8	51
Turtles	6	195*
Other reptiles	2	3

*includes two individual marked over 20 years ago

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

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

The U.S. Forest Service (USFS) and SRFS established four replicated experimental plots

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

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

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

Our approach is to use drift fences with pitfall and funnel traps to determine the species richness and relative abundances of amphibians and reptiles. The pitfall traps are used to capture salamanders, anurans, lizards, and small snakes. The funnel traps are used to capture larger snakes, lizards, anurans, and salamanders. The drift fences are set out in perpendicular arrays in the center of each treatment plot to capture animals moving in all directions. To optimize the sampling time of year and to allow the treatments to begin to have an effect on herpetofaunal diversity and abundances, we will sample for 3 months in the Spring of 1997. We will sample the drift fences every day on alternate weeks (i.e., one week on, one week off). Sampling may continue after this time, but will be contingent on obtaining additional funding. When captured, amphibians and reptiles will be identified, counted, and marked (either toe-clipped or pit-tagged) to allow us to determine species richness and relative abundances.

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

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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 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 fields 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 Environmental Toxicology 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

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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

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

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

During the past year, SREL scheduled more than 200 lectures, 50 tours, 26 workshops and 13 exhibits. One exhibit, the Palmetto Sportsman's Classic in Columbia, 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 distribution of news releases to a regular list of about 500 media affiliates, officials of DOE, and the University of Georgia. The program also has promoted various research projects through coverage in local and national media and has worked to enhance the laboratory's internal communications. Included among these have been coverage of SREL research by CNN, *U.S. News and World Report*, Associated Press, *BioScience*, *Earth Magazine*, *National Wildlife Magazine*, and National Public Radio. This program also has been responsible for planning and 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 quarterly basis, the other weekly, and an increased number of video projects. A 27-minute six-projector automated slide presentation about SREL research has become a regular part of SREL tours. A full-color poster that describes the life history of several species of freshwater turtles was distributed to elementary schools in Georgia and South Carolina. A teacher's guide accompanies the poster. This poster has received high praise from educators across the region.

This program also has produced and distributed two publications: *Outdoor Classroom Planning Guide* and *Biodiversity: Prospect & Promise for the Savannah River Site*. The Guide gives instructions for setting up a variety of outdoor classroom stations and outlines activities and investigations in which teachers can guide students through hands-on learning experiences in natural settings. The biodiversity brochure highlights the site's vast natural resources, explains biodiversity in general and defines its various types, such as genetic diversity. This publication received the "Best PR Magazine" award from the CSRA Chapter of the Society of Professional Journalists. Other projects in progress include a wetlands poster, a new set of fact cards and a National Environmental Research Park brochure.

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

Ecological Effects of the Par Pond Drawdown: Wildlife Studies

I.L. Brisbin, Jr.

This program provides a basic ecological context to the studies of contaminant fate and effects which are being undertaken in the program of Wildlife Radioecology, undertaken in the Division of Biogeochemistry of the SREL. The present program documents the basic natural history, general ecology, movement and behavior of those wildlife species which are of special concern because of their potential to act as vectors of radionuclides, heavy metals, or other site-generated contaminants to the foodchain of the hunting public. Of particular concern in this regard are the abundant populations of winter migratory waterfowl, resident breeding populations of wood ducks and upland game birds such as mourning doves, which may enter the SRS site, feed in contaminated habits, and then rapidly move offsite where they could be legally harvested by hunters and consumed as food.

While some data collected from opportunistic observations of wildlife during the course of other related studies (e.g., radionuclide uptake determinations), particular efforts have been made to trap and place radiotransmitters on a number of adult alligators which have been resident in the Par Pond reservoir throughout the period of reservoir drawdown and completion of the subsequent refill process. Using these radiotransmitters to relocate adult breeding females periodically has allowed the determination of reproductive effort (e.g., clutch sizes, hatching success, etc.) in these alligators throughout the reservoir drawdown and refill processes. The documentation of a diminished body condition of hatchling alligators seems to have been associated with the drawdown of the reservoir and its subsequent impact on the alligators' prey base.

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

Studies of wood ducks using nest boxes in the Par Pond reservoir system have emphasized the uptake of mercury contamination and are to be undertaken in cooperation with the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) of Rutgers University. With support provided by the latter organization and from the Interdisciplinary Program in Toxicology at the University of Georgia, mercury levels have been documented in the eggs of wood ducks nesting in the Par Pond reservoir and these levels are now being related to any possible alteration of DNA base-pair sequences of the cytochrome-b gene in the ducklings produced by these eggs.

Screech owls which showed leg abnormalities when discovered in a Par Pond nest box in 1995 have now been moved to the Patuxent Environmental Science Center of the National Biological Service, where they have been paired and bred with normal captive owls. These breedings have now produced offspring with similar leg abnormalities at the Patuxent Center, and further studies are planned to document the pattern of heritability of this condition and thereby determine the extent to which it may or may not be related to contamination levels found at the Par Pond CERCLA site.

Future work in this program will particularly emphasize studies of the wildlife resident on and

around L-Lake. An effort will be made to determine the basic ecological characteristics of these populations and thereby predict their responses to any future drawdown or elimination of that reservoir as a result of the SRS program in the shutdown of the river water system at the site.

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

G.K. Meffe

The littoral zone is transitional between 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 year, examinations of fish community structure and fish abundance in the littoral zone of Pond C began, and will document the recovery process. Three regular sampling locations were established along the shoreline of Pond C and collections of fishes were made with seines. These collections, to be conducted on a quarterly basis, are restricted to the shallow littoral zone, and involve multiple passes with small-mesh bag seines of eight to 30-foot lengths. All larger fish are identified, measured, and released at the sites; smaller individuals are identified and counted in the field, or, if too small, are 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 and Whole Body Lipids 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. 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.

Since 1991, a total of seventeen species of fish were caught, and data were collected on 9,242 individual fish during the four collection periods. 4,673 fish were individually marked with

permanent tags, of which 511 were recaptured. The two species of numerically dominant fish (excluding mosquitofish) during all four periods were bass, which accounted for 22 - 61% of the assemblage, and bluegill, which accounted for 18 - 41%. The number of species increased from five during reactor operation to about 12 during the period following reactor operation.

During 1994, 1995, and thus far in 1996, we have added 4,224 and 5,951 captures of fish to the Par Pond and Pond C data bases, respectively. In Par Pond, 19 species, and in Pond C, 17 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. New species entering the pond during the past three years were yellow perch, black crappie, redbreast sunfish, war mouth, 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.

The refilling of Par Pond and Pond C begun during the fall of 1994 presents a unique opportunity in 1996 to document changes in the composition and relative abundance of fish species found in this reservoir system. Data from the research described below will allow an assessment of the chronic effects of environmental perturbations (both thermal and water-level) on fish assemblages.

During 1996, electro-shocking of Par Pond and Pond C will be continued on a bi-monthly basis in an effort to obtain data on the composition and relative abundance of fish species inhabiting these previously impacted reservoirs. The mark-recapture study that we initiated as part of the sampling protocol will allow determinations of the population size and stability of fish species in these reservoirs.

We have sampled Pond C and Par Pond bluegill to determine the reproductive state of females, their body condition, and whole body lipids. Bluegill from heated (Pond C) and normothermic (Par Pond) sites were compared to determine how dynamic lipid and reproductive cycles are modified by thermal perturbation from a nuclear production reactor. Fish samples were collected monthly from both sites, over a 12 month period during the years 1986 - 1987. Additional samples have been taken during the reproductive season from 1988 through 1995. Sex was determined for bluegill from each site and reproductive condition was determined for adults. Bluegills were separated into liver, gonads, and body, and non-polar lipid amounts were determined for each compartment using an ether soxlet apparatus. Bodies of bluegills were shown to contain over 90% of the stored non-polar lipids. Overall, the percent body lipids of Pond C bluegill were twice as high as that of Par Pond bluegill. The highest percent body lipids occurred in both ponds during the reproductive months with the lowest lipid levels occurring during winter.

During a prolonged reactor down period, when both ponds were at normothermic temperatures, body lipids of bluegill from Pond C increased at a rate of approximately 3% of body weight per week for both adults and juveniles, whereas the rate of increase of lipids in Par Pond bluegill was less then one percent per week. The pattern of lipid deposition observed in Pond C bluegill corresponds with the establishment of a forage base within Pond C during the long reactor down periods.

Recent Publications: Par Pond Drawdown: Wildlife Studies

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

Impacts of water level and chemistry changes in SRS reservoirs: cycling and accumulation of mercury and trace metals

C.H. Jagoe

Pollutants of concern on SRS include trace metals, such as mercury. Some 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 concerning acceptable levels of mercury in human foods. Mercury in fish may also present a hazard to pisciverous wildlife. Therefore, any alterations in mercury bioavailability associated with environmental disturbances raise potential human health and ecological risk issues. The purpose of this research is to study the potential effects of major fluctuations in water level or water chemistry on the cycling and bioavailability of potentially-toxic trace metals such as mercury. Efforts to date have focused on the impacts of the Par Pond drawdown and refill on mercury cycling in Par Pond, especially impacts on gamefish. This work also considers mercury accumulation in other biota, and mercury dynamics in other systems for comparative purposes.

Mercury bioavailability is largely controlled by methylation rate and water chemistry. Inorganic mercury entering a system is converted to an organic form (methyl mercury) that is 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 probably increased both bacterial activity and the release of dissolved organic matter, which in turn increased mercury methylation and mobility.

Samples of largemouth bass were collected at quarterly intervals from Par Pond beginning in 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. Larger fish had higher mercury concentrations. Most adult bass exceeded 0.5 mg Hg/kg wet mass, 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, and food resources became scarce, condition factor began to decline. About six months after the drawdown, there was a transient increase in muscle mercury concentration in bass, possibly related to changes in diet. However, through the drawdown period until refill began, there was no significant overall trend in bass mercury content. Mercury content of bass muscle began to increase after Par was refilled in late winter 1995. Bass collections have continued through the summer of 1996, 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. Analysis of samples collected before refill showed that forage species varied considerably in mercury content, and were highest in brook silversides (mean 0.13 mg Hg/kg wet mass).

Mercury concentrations typically increase with trophic level, (biomagnification) and levels in long lived, top-level predators can become quite high. Alligators represent such predators in Par Pond and other SRS waters. In samples from about 50 Par Pond alligators, mercury averaged 17 mg Hg/kg dry mass in liver and 2.2 ppm in blood. For comparison, alligators were sampled from an area of the Florida Everglades known to be highly contaminated with mercury. These contained much more mercury in their internal organs than Par alligators, but muscle mercury concentrations were similar. Alligator samples for comparison purposes were also obtained from central Florida and the Okefenokee swamp in south Georgia. We were unable to detect changes in alligator mercury concentrations in Par Pond after refill, but speculate that this could be related to small sample sizes, or the short time period between refill and sampling. We are continuing to sample alligator tissues to detect longer-term trends. We attempted to correlate mercury levels in 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. Results to date suggest that while Hg levels in these tissues are related to concentrations in internal tissues, the variability is too high to allow accurate predictions on an individual basis. Sampling these readily obtainable tissues may be useful for population-level screenings, however.

Mercury and other trace metals in fish in other SRS waters are also an area of interest. Yellow bullheads were collected from Pond B in 1990 and again in 1994. Most were analyzed for muscle Hg and ^{137}Cs, and a subsample for Cd, Cu, Pb and Zn. Radiocesium body burdens reached an asymptote at about age 3, and did not increase further with fish age. In contrast, mercury concentrations continued to increase over the life of the fish. Fish age was a much better predictor of mercury content than fish size. Three year old bullheads from Pond B contained about 4500 bq ^{137}Cs/kg wet mass, and about 0.5 mg Hg/kg wet mass. Concentrations of the other trace metals were very low and not related to size or age. One manuscript detailing these findings is in press and another in preparation.

Much work on mercury in fish emphasizes their role as a dietary item for man or other animals, rather than considering potential effects of mercury on the fish themselves. However, dissolved mercury interferes with ion and osmoregulation and causes gill damage. We demonstrated that exposure to relatively high levels of dissolved Hg caused gill pathologies consistent with osmoregulatory stress. In a subsequent study, bass were sampled from Par Pond and L-Lake on the SRS, and from Thurmond Lake. Bass from the 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. Gill Na^+, K^+ ATPase activity did not vary among locations and was not correlated with fish mercury concentrations. These results were different than those reported for marine fish, where gill ATPase activity decreased in fish with high muscle mercury levels.

Sampling of bass and other biota will continue in 1996. Samples from Par will help detect refill related effects. We are presently using cold-vapor atomic fluorescence (CVAF) to allow measurement of mercury at low concentrations and in very small samples. Further development of this technique will allow accurate mercury speciation studies, and potentially the determination of mercury in soils, water and precipitation necessary for cycling and budget studies. Future management scenarios for L-Lake include considerable alterations in water level and possibly water

chemistry. We have begun initial sampling in this location in anticipation of such perturbations. An initial survey of several Carolina bays in the summer of 1996 showed detectable mercury in all fish sampled, and many benthic invertebrates. As these locations did not receive mercury contaminated water from the Savannah River, we hypothesize that mercury in these systems is entering via atmospheric transport, as widely reported in other areas. Sampling of bays and other wetland locations will continue to address this possibility, and to assess potential ecological impacts.

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Haines, T.A., V.T. Komov, V.E. Matey, and C.H. Jagoe. 1996. Perch mercury is related to acidity and color of 26 Russian lakes. Water, Air Soil Pollution 85:823-828

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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. Instrumental imprecision and chance variation are components of every measured environmental quantity. Statistical analysis seeks to extract accurate conclusions from imprecise data and to quantify the uncertainty about those conclusions. Better statistical methods provide two benefits for environmental restoration and remediation: 1) more accurate conclusions from limited data and 2) less data needs to be collected to reach sufficiently accurate conclusions. Our work concentrated on three projects: the analysis of toxicant accumulation curves, the assessment of spatial patterns, and the analysis of change in species composition.

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 cesium concentration). Each observation contains two sources of variation: variation among ducks in feeding behavior and metabolism, and variation among replicate cesium 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 or blown 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.

Our third project involves methods to analyze the effect of environmental change on plant and animal communities. Extant methods are adequate for analyzing trends in simple variables such as temperature or pH, but not for complex variables such as species composition. Good, statistically powerful techniques for detecting trends in species composition could be used to identify low level, chronic effects of SRS operations before such effects create obvious and expensive problems. Further, such methods are an absolute requirement for monitoring the efficacy of Carolina Bay restoration and other restoration such as that following the proposed draining of L-lake. Because species composition will change even in the absence of impacts (e.g., succession), some form of calibration is required to infer potential impacts and predict subsequent ecosystem consequences. We have extended techniques for detecting differences in species composition for analysis of temporal change for the case of control vs. potentially impacted sites monitored over time. We are working

on more general approaches to calibration applicable when there are no well-defined corresponding unimpacted sites.

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

The Savannah River National Environmental Research Park (NERP) is an outdoor laboratory for study of the environmental impacts of human activities, ecological research, and informing the public of land use 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 also should have programs planned to address these following 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 D.C., but the final disposition of the NERP program has fallen to local DOE officials because it is no longer supported nationally 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), a representative from the Savannah River Forest Station, and the NERP Director. The NERP Committee received 14 proposals and was able to fund the top five-ranked at about 90% of their requested amounts. The funded projects were:

1. "A Large-Scale Experimental Approach to Determine the Effects of Coarse Woody Debris on the Species Richness and Relative Abundance of Amphibians and Reptiles of the Savannah River Site" -- This research is part of a group of experiments being carried out by SRFS and SREL exploring the influence of landscape management practices relevant to land stewardship and management of the SRS and its natural resources. One of the most important components of proper management of forested lands is determining the habitat requirements of animals and how their habitat is affected by specific management practices. The overall goal of this research is to determine the effects of coarse woody debris on the herpetofauna of the SRS.

2. "Conservation Genetic Study of Freshwater Lampsiline Mussels" -- This research involves partners from the National Biological Survey and the U.S. Fish and Wildlife Service. The project will use DNA RFLPs to assess genetic diversity within and among populations, and among species in the genus *Villosa*. We will then use *Villosa* as a model to 1) evaluate species status of rare lampsilines; 2) compare levels of genetic variation on abundant and rare taxa, and; 3) evaluate phylogenetic relationships among lampsiline mussels. Freshwater mussels are one of the most imperiled faunal elements in North America. Knowledge of population genetic structure will add significantly to our ability to manage this declining fauna as we practice good stewardship of federal lands

3. "A Large-scale Experimental Test of the Effects of Landscape Pattern on *Cnemidophorus*

sexlineatus" --The corridor concept has been offered as a viable tool in the efforts to conserve biodiversity. This research will test the influence of landscape pattern on the dispersal of the six-lined racerunner, focusing on whether habitat corridors facilitate the movements of individuals between habitat patches. The proposed experiment is also part of the group of experiments being carried out by SRFS and SREL exploring the influence of landscape management practices relevant to land stewardship and management of the SRS and its natural resources.

4. "Flow Cytometric Analysis of the Effects of Fly Ash Contaminants on Small Mammals" -- Small mammals are a model group for *in situ* monitoring of terrestrial contamination. The purpose of this study is to determine the effects of fly ash contaminants on small mammals, by: 1) determining the concentration of metals in the tissues of cotton m ice and cotton rats in contaminated and control sites, and; 2) comparing the extend of their DNA damage.

5. "The Development and Application of Sequential Flow-through Extractions" -- The goal of this research is to gain increased knowledge of how kinetics affect the metal distribution in soils. The flow-through sequential extraction method should provide information which could aid in determining which soils present the most immediate risks as a source of metal contaminants, and provide direction as to the most appropriate remediation techniques.

DOE Research Set-Aside Areas

C.E. Davis

The purpose of the Set-Aside program is to establish and maintain areas 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 of SRS site operations and forest management activities. Through the Set-Aside program, the protection and preservation of these areas not only aid in sustaining a high degree of biological diversity on the site, but also fulfill the Department of Energy's (DOE) desire to maintain the SRS as a National Environmental Research Park (NERP) and the policy objectives of DOE-Environmental Management.

GIS Development and Boundary Lines. The Savannah River Ecology Laboratory (SREL) continued to develop a computer based Geographical Information System (GIS) data layer describing the Set-Aside boundaries. Changes to this working coverage included: 1) replacing ERDAS digitized boundary lines with ARC-INFO digitized lines; 2) incorporating Global Position System (GPS) lines into the boundary line coverage; and 3) initiating a vegetation community type GIS layer for each Set-Aside area. All available SRS coverages (where applicable) were incorporated into this vegetation layer for resource and risk assessment informational purposes. Maps generated from these coverages are in support of the final NERP publication describing the Set-Aside areas. The boundary line GIS layer is used on site to ensure that Set-Aside boundary lines are available for consideration by SRS groups making land management decisions. SRS's Site Use Permit grid maps as well as SRFS's Resource Compartment maps now include the Set-Aside areas. Cooperation between SREL and the SRFS continues as these the two groups determine the feasibility of using the Global Position System (GPS) to verify and update the Set-Aside boundaries. Approximately 29.5 miles was GPSed by the SRFS in the Mill Creek area. QA standards for using SRFS GPS data are under negotiations for the

purposes of coverage comparisons and area accuracy assessments.

Periodic inspections of Set-Aside boundary postings were conducted where potential conflicts were anticipated and approximately 6.2 miles of line were refurbished with signs.

Natural Resource Management and Coordination. SREL's Set-Aside research coordinator continued to participate as an ID team member in the SRFS's prescription review process for developing natural resource 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. Erosion control and restoration efforts by the SRFS and the NRCS were initiated this FY at the ATTA range to prevent further impacts into Reedy Branch. Set-Aside boundary lines were coordinated with the Three Rivers Landfill and *Paulownia* project personnel. The US Army Corp of Engineers coordinated with SREL for a bridge replacement over UTRC at Road F to minimize negative impacts into the Whipple/OHER Set-Aside. SREL coordinated with the SRFS and SCE&G for maintenance activities of utility rights-of-way crossings through Set-Asides.

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. The proposal titles were:

1. Survey of Spiders on the SRS
2. Loop readers as technique for automated data collection in studies of animal populations
3. Continued monitoring of fishes in isolated wetlands and test of an empirical model to predict their presence or absence
4. Amphibian research in Ginger's Bay Set-Aside
5. Using automated recording systems to monitor Anurans and birds on the SRS

SREL continued numerous long-term plant and animal studies in Set-Asides and initiated new studies this fiscal year, including a comparative macroinvertebrate colonization stream study, a toad distribution study, a tree frog growth study, and a study investigating movement patterns of small mammals in an experimental landscape.

Groups other than SREL also continue to use the Set-Aside areas. Research continues on coarse woody debris decomposition, softmast production in bottomland hardwood forests, and archaeological investigations around Carolina bays. New research was initiated this year to evaluate historical data bases (e.g, 1960's specimen collections) linked with original study sites for the purposes evaluating trends over time and developing population monitoring plans. An experimental prescribed burn was conducted on a small portion of the Craig Pond Set-Aside for enhancement of the pitcher plant population. Meyers Branch was established as the control stream for restoration projects associated with the Pen Branch Corridor and Risher Pond continues to provide control animals to compare with ash basin contaminant studies. Educational outreach use of the Set-Aside areas continued to increase this year from both SREL and SRFS's programs.

Data archiving capabilities were established with SREL's computer services for the initial purpose of linking research publications with particular Set-Asides. It is anticipated that future coding for archived data will include a linkage between Site Use permits and a Set-Aside area. This will increase the capability of making linkages between a researcher's raw data, the study plot

locations (i.e, habitat type used), and a final publication.

Management Plans. Reference materials for each Set-Aside area continue to be evaluated for formulating the desired future conditions of the Set-Asides and for determining what research or management activities are appropriate for particular Set-Aside areas. A historical records search will be initiated for 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 historical information, photos, maps, and publications and research efforts.

Future accomplishments for the Set-Aside program will focus on publishing the NERP document on Set-Aside areas, soliciting input from the SCDNR Heritage Trust program and the SC Nature Conservancy for the development of 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. Metadata for the latest version of the Set-Aside GIS will be written to meet site standards and a new version will be released in FY97. 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]

Belk, M.C. and M.H. Smith. 1996. Pelage coloration in oldfield mice (*Peromyscus polionotus*):antipredator adaptation? Journal of Mammalogy 77:882-890.

Bodie, J.R., K.R. Smith, and V.J. Burke. 1996. A comparison of diel nest temperature and nest site selection for two sympatric species of freshwater turtles. American Midland Naturalist 136:181-186.

Brooks, M.J., B.E. Taylor and J.A. Grant. Carolina Bay geoarchaeology and Holocene landscape evolution on the Upper Coastal Plain of South Carolina. Geoarchaeology (in press).

Davis, C.E. and D.J. Karapatakis. 1996. GIS dataset of Set-Aside boundary lines - file SETASIDE (DRAFT - Version 5). SREL Metadata for GIS. Savannah River Ecology Laboratory, Aiken, S.C.

Hartman, G.D. 1995. Age determination, age structure, and longevity in the mole, *Scalopus aquaticus* (Mammalia: Insectivora). Journal of Zoology 237:107-122.

Herbert, B.E. and P.M. Bertsch. 1995. Characterization of dissolved and colloidal organic matter in soil solution: A review. p. 63-88. In Eighth North American Forest Soils Conference: Carbon Forms and Functions in Forest Soils, (eds.) William W. McFee and J. Michael Kelly. Soil Science Society of America. Gainesville, FL.

Jagoe, C., A. Faivre, and M. Newman. 1996. Morphological and morphometric changes in the gills of mosquitofish (*Gambusia holbrooki*) after exposure to mercury (II). Aquatic Toxicology 34:163-183.

Jagoe, C.H. and D. Welter. 1995. Quantitative comparisons of the morphology and ultrastructure of erythrocyte nuclei from seven freshwater fish species. Canadian Journal of Zoology 3:1951-1959.

Jenssen, T.A., J.D. Congdon, R.U. Fischer, R. Estes, D. Kling, and S. Edmands. 1995. Morphological characteristics of the lizard, *Anolis carolinensis*, from South Carolina. Herpetologica 51:401-411.

Jung, R.E. and C.H. Jagoe. 1995. Effects of low pH and aluminum on body size, swimming performance and susceptibility to predation of green treefrog (*Hyla cinerea*) tadpoles. Canadian Journal of Zoology 73:2171-2183.

Kean, C. and T.D. Tuberville. 1995. *Seminatrix pygaea* (Black swamp snake) size. Herpetological Review 26:103.

Krenz, J.D. and D.M. Sever. 1995. Mating and oviposition in paedomorphic *Ambystoma talpoideum* precedes the arrival of terrestrial males. Herpetologica 51:387-393.

Lide, R.L. When is a depressional wetland a Carolina Bay? Southeastern Geographer. (in press)

Megonigal, J.P., S.P. Faulkner, and W.H. Patrick. 1996. The microbial activity season in southeastern hydric soils. Soil Science Society of America Journal 60:1263-1266.

Moorhead, K.K. and J V. McArthur. 1996. Spatial and temporal patterns of nutrient concentrations in foliage of riparian species. The American Midland Naturalist 136:29-41.

Niewiarowski, P.H. 1995. Effects of supplemental feeding and thermal environment on growth rates of eastern fence lizards, *Sceloporus undulatus*. Herpetologica 51:487-496.

Pechmann, J.H.K. 1995. Use of large field enclosures to study the terrestrial ecology of pond-breeding amphibians. Herpetologica 51:434-450.

Pickens, R.M. and C. H. Jagoe. Relationships between precipitation and surface water chemistry in three Carolina bays. Archiv Fur Hydrobiologie (in press).

Pinder, J.E., III, F.B. Golley, and R.F. Lide. 1995. Factors affecting limited reproduction by loblolly pine in a large old field. Bulletin of the Torrey Botanical Club 122:306-311.

Poiani, K.A. and P. M. Dixon. 1995. Seed banks of Carolina bays: Potential contributions from surrounding landscape vegetation. The American Midland Naturalist 143:140-154.

Reese, R.E. and K.K. Moorhead. 1996. Spatial characteristics of soil properties along an elevational gradient in a Carolina bay wetland. Soil Science Society of America Journal 60:1273-1277.

Richards, C. and P.L. Leberg. 1996. Temporal changes in allele frequencies and a population's history of severe bottlenecks. Conservation Biology 10:832-839

Seigel, R.A., R.K. Loraine, and J.W. Gibbons. 1995. Reproductive cycles and temporal variation in fecundity in the black swamp snake, *Seminatrix pygaea*. The American Midland Naturalist 134:371-377.

Semlitsch, R.D., J.W. Gibbons, and T.D. Tuberville. 1995. Timing of reproduction and metamorphosis in the Carolina Gopher frog (*Rana capito capito*) in South Carolina. Journal of Herpetology 29:612-614.

Sever, D.M., L.C. Rania, and J.D. Krenz. 1996. Reproduction of the salamander, *Siren intermedia* Le Conte with especial reference to oviductal anatomy and mode of fertilization. Journal of Morphology 227:335-348.

Sheldon, A.L. and G.K. Meffe. 1995. Path analysis of collective properties and habitat relationships of fish assemblages in coastal plain streams. Canadian Journal of Fisheries and Aquatic Sciences 52:23-33.of Ambystoma opacum.

Taylor, B.E. and D.E. Scott. The effect of larval density dependence on population dynamics of *Ambystoma opacum*. Herpetologica.

Trauth, S.E., D.M. Sever, and R.D. Semlitsch. 1994. Cloacal anatomy of paedomorphic female *Ambystoma talpoideum* (Caudata: Ambystomatidae), with comments on intermorph mating and sperm storage. Canadian Journal of Zoology 72:2147-2157.

Tuberville, T.D., J.W. Gibbons, and J.L. Greene. 1996. Invasion of new aquatic habitats by male freshwater turtles. Copeia 3:713-715.

Whitaker, J.O., Jr., G.D. Hartman, and R. Hein. 1994. Food and ectoparasites of the southern short-tailed shrew, *Blarina carolinensis* (Mammalia: Soricidae), from South Carolina. Brimleyana 21:97-105.

U.S. Department of Energy, SROO-SRS. 1995. Environmental assessment for the construction and operation of the Three Rivers Soild Waste Authority Regional Waste Management Center at the Savannah River Site. DOE/EA-1079.

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

A. NOTEWORTHY EVENTS AND SPECIAL ACTIVITIES

A major activity for SREL in FY96 has been the development of a new contract for the operation of the SREL. The Department of Energy (DOE) requested SREL's contract be converted to a new Cooperative Agreement. The SREL is the first Management and Operating (M&O) contractor throughout the Department of Energy to change to a Cooperative Agreement. The M&O contract under which SREL operated through the UGA Research Foundation was in effect since 1973. It was the longest running contract on the Savannah River Site and has brought over $130 million into the University of Georgia. The new Cooperative Agreement was signed on June 18, 1996. This agreement should provide SREL greater flexibility in operating within the DOE structure. Under the new Cooperative Agreement, SREL will be given greater ability to work with the State of South Carolina regulators in complying with the various environmental and radiological statutes. Many of the regulatory requirements of the Laboratory's operation will be determined by the new Necessary and Sufficient Process set up by the Department of Energy. This process will be conducted by SREL regulatory personnel in conjunction with DOE oversight.

A Small Animal Care Facility located at the main SREL complex was begun in FY96. This project is being built under a design-build contract through Westinghouse Savannah River Company, and is due to be completed in November 1996. The building will be state-of-the-art construction for housing small animals using NIH and USDA codes for animal care. The facility is being constructed at a cost of $1,240,000. Other construction projects under way for SREL in FY96 are the laboratory addition to the present SREL lab facility at a cost of $1,700,000 and the SREL Receiving Building at a cost of $735,000. The laboratory addition will house laboratories for research initiatives in Molecular Ecology, Bioremediation, and triple the laboratory space available for analytical equipment. The receiving building completion in March of 1996 allowed SREL to convert the old facility into offices for 13 technical staff and visiting scientists. The laboratory also has additional funding for an up-grade of the present greenhouse during FY97. This will increase the total square footage of SREL facilities to over 100,000 ft^2 and provide new facilities to continue world class ecological research.

SREL converted its major computer system from a mini-computer driven operation to a client-server system in FY96. This new system provides SREL with a network for scheduling conferences, preparing calendars, and communicating electronically within the laboratory as well as outside the lab. Also, a new Internet connection allows SREL personnel to directly log onto the World Wide Web and communicate with colleagues all over the world. This process, although very time consuming in its set-up has saved SREL operating funds by reducing license fees. SREL has also been working on up-grading its accounting systems in FY96. A new windows based system is under development and should be on-line by the beginning of the new government fiscal year. This system will replace outdated software and time consuming data entry by electronically entering data available through the University of Georgia.

A Fourier Transform Ion Cyclotron Mass Spectrometer (FTMS) was purchased with funds from the Georgia Lottery, SREL, and a matching grant from the U.S. Department of Energy. This $540,000 instrument will greatly enhance SREL's researchers' ability to identify the chemical

composition of polar, thermally unstable or high molecular weight compounds that present difficulties using current techniques. These efforts will allow scientists to identify organic contaminants in the environment, assess their ecological risk, and aid in the design of appropriate remediation strategies for cleanup at the Savannah River Site or other contaminated sites.

SREL has had a program in place during FY96 to reduce travel costs by twenty percent. This is part of a DOE effort to cut travel costs for the SRS complex by $100 million. SREL has been able to do this thus far by reducing trips and travel costs.

Chernobyl research headed by **Dr. Ronald Chesser**, with collaboration by **Drs. Michael Smith** and **Charles Jagoe** (SREL), Cham Dallas (UGA), and Robert Baker (Texas Tech University) was featured in several television and radio broadcasts and popular print articles, including ABC's World News Tonight, a one-hour CNN Presents "Chernobyl: Legacy of a Meltdown," live interviews on National Public Radio and BBC broadcasts, and articles in *U.S. News and World Report, American Scientist, New Scientist, Chronicle of Higher Education, La Recherche, Washington Times, New York Times, Fort Worth Daily News, The State, Aiken Standard, Augusta Chronicle, The European, and the London Times.*

SREL has purchased the hardware and a building to house four classrooms to develop a Distance Learning Center. Program Coordinator **Bill Lowell** obtained a commitment from Dr. Prokasy (UGA Vice President for Academic Affairs) to provide $30,000 in equipment to help connect SREL to the University's distance learning network. This will enable SREL faculty to teach courses "on campus" via two-way audio and video without leaving SREL. It will also allow students in residence to tap into the University's course offerings. This facility will come "on-line" this fall with a course in Radioecology taught by **Drs. Ward Whicker, Ronald Chesser, Tom Hinton,** and **L Lehr Brisbin, Jr**.

Drs. J V. McArthur and **Peter Koestier** co-organized the Third Savannah River Symposium on Environmental Science. The symposium, "New Concepts in Stream Ecology: An Integrative Approach", was held at the University of Georgia Conference Center and featured 15 invited national and international speakers. The two day symposium averaged 40 participants per day.

The Department of Energy's Office for Science, Technology, and Business Development asked SREL to coordinate the development of proposals for National Centers of Excellence for Water, Soils, and Radioecology among the ERDA and SCUREF Universities. **Drs. Rebecca R. Sharitz** and **Gary Mills** coordinated the National Water Research Center, **Drs. Domy Adriano** and **Michael Newman** coordinated the National Soil Remediation Research Center, and **Drs. Ronald Chesser** and **Thomas Hinton** Coordinated the International Initiative in Radioecology. The first call for proposals for these three centers was June 21, 1996.

This year the National Environmental Research Park (NERP) committee received 14 proposals totaling over $200,000 in requests. Although the great majority of the proposals were excellent, the committee was able to fund only the top-ranked five proposals at about 90 percent of their requested amounts ($65,300). The awards were made as follows:

1 — M. Dorcas and J. Congdon. "A Large-scale Experimental Approach to Determine the Effects of Coarse Woody Debris on the Species Richness and Relative Abundances of Amphibians and Reptiles on the Savannah River Site"

2 — M. Mulvey, H. Liu, J. Williams (NBS), Box (NBS), and R. Butler (USFWS). "Conservation Genetic Study of Freshwater Lampsiline Mussels"

3 — R. Cheney. "A Large-scale Experimental Test of the Effects of Landscape Pattern on *Cnemidophorus sexlineatus*"

4 — J. D. Peles and G. W. Barrett. "Flow Cytometric Analysis of the Effects of Fly Ash Contaminants on Small Mammals"

5 — A. L. Bryce. "The Development and Application of Sequential Flow through Extractions".

Dr. Gary Meffe taught several symposia on the principles of ecosystem management for the U.S. Fish and Wildlife Service and the Bureau of Land Management. Dr. Meffe also cooperated with two scientists from The Nature Conservancy to write a handbook to be used by the U.S. Department of Defense for better stewardship of military lands with respect to biodiversity.

Dr. Michael Newman taught a five-day course titled, "Quantitative Methods in Ecotoxicology," at the SREL Conference Center. The course objective is to present quantitative methods for the analysis of ecotoxicological data and to apply them with PC-based software. Dr. Newman also authored a book titled *Quantitative Methods in Aquatic Ecotoxicology*. The book describes quantitative and statistical methods for predicting the effects of pollutants at all ecological levels, and it includes more than 70 examples of assessing toxicant effects based on quantitative methods. Dr. Newman also co-edited a book titled *Ecotoxicology: A Hierarchical Treatment* which is based on a symposium held in 1994 to identify and present the fundamental concepts of ecotoxicology at various levels of biological organization.

Dr. I. Lehr Brisbin, Jr. co-hosted a meeting of the Crocodile Special Interest Group, held at the Riverbanks Zoo, Columbia, SC.

The new Advanced Analytical Center for Environmental Sciences (AACES) successfully completed its second year of operation. Programs were initiated in environmental chemistry, analytical applications and environmental computational chemistry; and collaborative projects were undertaken with industry, government agencies and universities. Dr. Brian Teppen of AACES taught a 3-day course titled *Introduction to Molecular Modeling of Environmental Systems.*

In addition to the funding received from the Department of Energy through its contract with the University of Georgia, SREL researchers also have received funding from other sources. This funding is in the form of both research grants and contract work. The funding provided by the 27 ongoing projects listed below totals $1,233,803 for DOE's 1996 fiscal year.

Principal Investigator(s): Domy C. Adriano
Project Title: Coal Ash Utilization
Funding Agency: Electric Power Research Institute
Funding Level FY96: $54,000

Principal Investigator(s): Paul M. Bertsch
Project Title: Advanced Analytical Center for Environmental Sciences
Funding Agency: ERDA
Funding Level FY96: $400,000

Principal Investigator(s): Paul M. Bertsch and Douglas Hunter
Project Title: The Biology of Aluminum Resistance and Toxicity in Plants
Funding Agency: The Sciences and Engineering Research Council of Canada
Funding Level FY96: $54,000

Principal Investigator(s): Paul M. Bertsch and John Seaman

Project Title: Colloidal Migration and Deposition of Sediments on the Savannah River Site
Funding Agency: Westinghouse Savannah River Company
Funding Level FY96: $141,000

Principal Investigator(s): I. Lehr Brisbin, Jr. and Larry Bryan
Project Title: Survey of Wading Birds in Coastal Marshes
Funding: PTI Environmental Services
Funding Level FY96: $14,000

Principal Investigator(s): I. Lehr Brisbin, Jr. and Larry Bryan
Project Title: Inventory Wading Birds in Georgia Coastal Plain
Funding Agency: Georgia Department of Natural Resources
Funding Level FY96: $28,000

Principal Investigator(s): I. L. Brisbin, Jr. and Larry Bryan
Project Title: Ecology of Woodstorks
Funding Agency: Georgia Department of Natural Resources
Funding Level FY96: $20,000

Principal Investigator(s):I. Lehr Brisbin, Jr.
Project Title: Birds as Bioindicators of Environmental Health
Funding Agency: Rutgers University: Consortium for Risk Evaluation with Stakeholder Participation
Funding Level FY96: $11,000

Principal Investigator(s): Sue Clark
Project Title: Geoscience Speciation at Mixed Waste Disposal Facility
Funding Agency: ERDA
Funding Level FY96: $50,000

Principal Investigator(s): Sue Clark
Project Title: Assay of Alpha and Beta Concentrations in Soil
Funding Agency: ERDA
Funding Level FY96: $70,200

Principal Investigator(s): Justin Congdon and Roy Nagle
Project Title: Diamondback Terrapin Egg Incubation
Funding Agency: PTI Environmental Services
Funding Level FY96: $6,236

Principal Investigator(s): Beverly S. Collins
Project Title: Bottomland Hardwood Experimental Gaps
Funding Agency: U.S. Department of Agriculture
Funding Level FY96: $45,700

Principal Investigator(s): Beverly S. Collins
Project Title: Baseline Survey of Understory Herbs
Funding Agency: WestVaco
Funding Level FY96: $3,000

Principal Investigator(s): Beverly S. Collins and Ronald Mumme (Allegheny State College)
Project Title: Avian Frugivory and Seed Dispersal
Funding Agency: U.S. Forest Service
Funding Level FY96: $7,000

Principal Investigator(s): J. Whitfield Gibbons
Project Title: Development of Turtle Populations as Bioindicators of Contamination on DOE Sites
Funding Agency: Rutgers University: Consortium for Risk Evaluation with Stakeholder Participation
Funding Level FY96: $11,000

Principal Investigator(s): Tracy Tuberville and J. Whitfield Gibbons
Project Title: Ecology of Gopher Tortoises in South Carolina
Funding Agency: South Carolina Department of Natural Resources
Funding Level FY96: $5,000

Principal Investigator(s): J Vaun McArthur
Project Title: Undergraduate Research-Research Experience for Undergraduates
Funding Agency: National Science Foundation
Funding Level FY96: $50,000

Principal Investigator(s): Gary Meffe
Project Title: Formulating and Testing Protocols for Developing IBI's at DOE Sites
Funding Agency: Rutgers University: Consortium for Risk Evaluation with Stakeholder Participation
Funding Level FY96: $11,000

Principal Investigator(s): Margaret Mulvey
Project Title: Research on Carolina Heelspitter
Funding Agency: South Carolina Department of Natural Resources
Funding Level FY96: $25,000

Principal Investigator(s): Margaret Mulvey
Project Title: Deep Phylogeny of Hydrobild Gastropods
Funding Agency: Smithsonian Institution
Funding Level FY96: $21,000

Principal Investigator(s): Margaret Mulvey
Project Title: Oval Pigtoe Molecular Genetics

Funding Agency: U.S. Fish and Wildlife Service
Funding Level FY96: $4,500

Principal Investigator(s): Margaret Mulvey
Project Title: Genetic Relationships in the *Villosa-Lampsilus* Mussel Complex
Funding Agency: U.S. Fish and Wildlife Service
Funding Level FY96: $2,917

Principal Investigator(s): Margaret Mulvey and Craig Stockwell
Project Title: Population Research on the Endangered Pupfish
Funding Agency: U.S. Department of Defense
Funding Level FY96: $100,000

Principal Investigator(s): Chris Romanek
Project Title: Light Element Analysis
Funding Agency: Lockheed Engineering and Sciences Co.
Funding Level FY96: $11,000

Principal Investigator(s): Barbara E. Taylor and Philip M. Dixon
Project Title: Comparative Risk Assessment of Climate Change and Other Anthropogenic Stressors: Habitat and Biological Diversity on the Savannah River Site
Funding Agency: U.S. Environmental Protection Agency
Funding Level FY96: $20,000

Principal Investigator(s): Barbara E. Taylor and Evelyn E. Gaiser
Project Title: Paleolimnological Reconstruction of Holocene Environments in Wetland Ponds of the Upper Coastal Plain
Funding Agency: National Science Foundation Doctoral Dissertation Program
Funding Level FY96: $5,750

Principal Investigator(s): Ward Whicker
Project Title: Radionuclides on the Savannah River Site
Funding Agency: ERDA
Funding Level FY96: $62,500

B. AWARDS, HONORS, AND OUTSTANDING RECOGNITION

Dr. Sue Clark was selected for a National Academy of Sciences committee on the Waste Isolation Pilot Plant. She is also editor of the newsletter of the Geochemistry Division of the American Chemical Society and on the program committee of the Nuclear Chemistry and Technology Division of the American Chemical Society.

Dr. J Vaun McArthur assumed the role of administrating the SREL Education Program. Dr. McArthur is responsible for the undergraduate and graduate students, high school students and Young Scholars, TRAC faculty and visiting faculty from other colleges and universities. Dr. McArthur's responsibilities also include coordinating the review and selection of applicants, matching visitors with mentors, coordinating program planning and the development of new educational programs offered by SREL faculty.

Graduate student **Vincent Burke** was awarded Best Student Paper for his presentation *A Terrestrial buffer zones and wetlands conservation; a case study of freshwater turtles in a Carolina bay* at the 9th annual meeting of the Society for Conservation Biology.

Dr. Thomas Hinton has been invited to serve a two-year term as a member of the Citizens Advisory Committee on public health and research activities at Department of Energy sites. The Committee provides advice and recommendations to the Centers for Disease Control on issues such as selection, design, scope and adequacy of health research; the dissemination of findings; and the design of future studies.

Bill Lowell was promoted to Program Coordinator and will be in charge of developing the Distance Learning Center at SREL.

Dr. Sue Clark received a 1995 DOE Health Physics Faculty Research Award. This program recognizes and supports the efforts of outstanding faculty members for doing creative research in areas related to radiation protection. Dr. Clark is conducting research to evaluate and improve existing methods for detecting alpha contamination in radiological emergencies and environmental assessments. Ultimately, the research may provide significant cost savings to DOE and other federal agencies.

The South Carolina Soil and Water Conservation Association gave its Merit Award to the Columbia Metropolitan Airport for its land reclamation project. **Dr. Domy Adriano** participated in the coal fly ash research portion of the project. Dr. Adriano's research was funded by the Electric Power Research Institute. The award is given to businesses or conservation groups who have made an impact on soil remediation and conservation. A plaque, given to the Columbia Metropolitan Airport, will hang in the airport for public viewing.

Tony Mills and Dr. J. Whit Gibbons received SRS Conservation Champs awards from the Savannah River Forest Station in January 1996. They were recognized for their involvement with various Forest Service-sponsored educational events. Gary Sick of the Savannah River Forest

Service presented the awards.

Dr. Rebecca Sharitz was the plenary speaker at the Graduate Student Research Symposium at the Institute of Ecology. The title of Dr. Sharitz's speech was *An Experiment in Community Involvement: Conservation management in the Edisto River Basin.*

Dr. Tom Hinton received a $3,500 grant from the University of Georgia's Research Foundation for *Chromosome Painting: A Novel Approach for Assessing Damage Across Levels of Biological Organization.*

The National Science Foundation's Research Experiences for Undergraduates awarded SREL $50,000 per year for two years, for the proposal titled *The impacts of energy technologies on natural environmental systems.* These funds will be used to sponsor undergraduate internships at SREL during the summers of 1996 and 1997.

Savannah River Ecology Laboratory graduate students received three of twelve $500 awards from the Society of Wetland Scientists Research Grant Scholarship Committee for work in wetland systems. **Loretta Battaglia** received the award for research titled "Influence of disturbance on heterogeneity and post-hurricane tree regeneration in an old-growth bottomland hardwood forest"; **Adrienne Edwards** for work titled "Population and metapopulation dynamics of *Sagittaria isoetiformis*, a rare wetland perennial" and **Susan Miller** for work titled "Dynamic morphology of grasses along a hydrochemical gradient: I. Vesicular-arbuscular mycorrhizae." All three students are under the supervision of **Dr. Rebecca R. Sharitz.**

Dr. Gary Meffe was chosen to serve a three- to four-year term on the Scientific Advisory Board of the Archibold Biological Station in Lake Placid, Florida.

Dr. J. Whitfield Gibbons was presented the 1996 State of South Carolina Environmental Awareness Award by Governor David Beasley.

Dr. J. Whitfield Gibbons received the Meritorious Teaching Award for 1995 from the Association of Southeastern Biologists. In addition Dr. J. Gibbons was elected as president-elect of the Association of Southeastern Biologists at the annual ASB meeting in Statesboro, GA.

Drs. Gary Meffe and Mike Newman were promoted from associate research scientist to senior research scientist at the University of Georgia.

Researcher **Rebecca Yeoman** was awarded a $500 grant for her proposal titled "Test of the Parental Investment in Care Hypothesis in Chelonians" from the Grants-in- Herpetology. Rebecca was also awarded $567 for her research project titled "Hatchling Turtles: What if There Were No 'Brown Bag Lunches'? or ("Experimental Reductions in Yolk Reserves in Hatchling Turtles: Is 'Fitness' Reduced?")," from the Theodore Roosevelt Committee.

The SREL Outreach Division was awarded the "Best PR Magazine" from the CSRA Chapter of the Society of Professional Journalists. The CSRA Chapter recognized the lab's publication titled,

"Biodiversity: Prospect and Promise for the Savannah River Site - A National Environmental Research Park."

Graduate student **Kurt Buhlman** received first place for 1996 Excellence in Research from the Graduate School at the University of Georgia for his paper titled "Prolonged egg retention in the turtle *Deirochelys reticularia* in South Carolina."

Graduate student **Robert Ford** received an award of $1,750 from the Clay Minerals Society for research on "The effects of aging and ligand interactions on partitioning of divalent metals adsorbed/coprecipitated with iron oxides."

III. PUBLICATIONS AND PRESENTATIONS

A. JOURNAL ARTICLES AND BOOK CHAPTERS PUBLISHED

SREL
Reprint No.

1963 Buhlmann, K.A. 1995. Habitat use, terrestrial movements, and conservation of the turtle, *Deirochelys reticularia* in Virginia. Journal of Herpetology 29:173-181.

1964 Mulvey, M.E., M.C. Newman, A. Chazal, M.G. Heagler, and L.S. Hales, Jr. 1995. Genetic and demographic responses of mosquitofish (*Gambusia holbrooki* Girard 1859) populations stressed by mercury. Environmental Toxicology and Chemistry 14:1411-1418.

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1978 Martin, H.W., R.L. Brigmon, and T.L. Morris. 1995. Diving protocol for sterile sampling of aquifer bacteria in underwater caves. The National Speleological Society Bulletin 57:24-30.

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1990 Lee, J.R. 1995. Review: Handbook of Snakes of the United States and Canada. Vols. 1-2. Albert H. Wright and Anna A. Wright. 1994. Cornell University Press, Ithaca, NY. Vol. 1 564 p., Vol. 2 540 p. Copeia 1995:753-754.

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grazing and rainfall interactions. Journal of Environmental Radioactivity 29:11-26.

2000 Bertsch, P.M. and D.R. Parker. 1996. Aqueous polynuclear aluminum species. p. 117-168. *In* The Environmental Chemistry of Aluminum, (eds.) by G. Sposito. 2nd ed.,CRC Press. Boca Raton, FL.

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2008 McLeod, K.W., G.R. Wein, and R.R. Sharitz. 1993. Wetland restoration for habitat reconstruction and contaminant stabilization. p. 1043-1047. *In* ER'93 - Environmental Remediation Conference, U.S. Department of Energy. Augusta, GA.

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2016 Chesser, R.K. and D.W. Sugg. 1996. Toxicants as selective agents in population and community dynamics. p. 293-317. *In* Ecotoxicology: A Hierarchical Treatment, (eds.) M.C. Newman and C.H. Jagoe. Lewis Publishers. Chelsea, MI.

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Bertsch, P.M., D.B. Hunter, and S.B. Clark. **Invited Speaker**. Synchrotron-based microanalytical techniques for the chemical speciation of metals and radionuclides in environmental samples. Federation of Analytical Chemistry and Spectroscopy Societies. Cincinnati, OH. October 1995.

Bertsch, P.M. and D.B. Hunter. **Invited Speaker**. Elucidating fundamental mechanisms in soil and environmental chemistry: The role of advanced analytical and spectroscopic methods. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. St. Louis, MO. October 1995.

Bertsch, P.M., J.C. Seaman, L. Schwallie, and W.J. Walker. *In-situ* remediation of CR (VI) contaminated soils and aquifer sediments. American Geophysical Union. San Francisco, CA. December 1995. Brisbin, I.L. Jr. **Invited Speaker**. Is the Red Junglefowl one of the most threatened birds in Asia: A plea for conservation concerns. The Fellows of the American Ornithologist's Union.

Cincinnati, OH. August 1995.

Bryan, A.L. **Poster.** Foraging habitat use of wood storks breeding in the coastal zone of Georgia, U.S.A. Colonial Waterbird Society. Victoria, British Columbia, Canada. November 1995.

Bryce, A., A.D. Lueking, S.B. Clark, S.M. Serkiz, and G.S. Yu. Factors affecting lanthanide and actinide adsorption to soils and model surfaces. American Chemical Society. New Orleans, LA. March 1996.

Buhlmann, K.A. and J.W. Gibbons. Terrestrial habitat use by aquatic turtles of Carolina bays: Implications for upland habitat conservation. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Buhlmann, K.A., J.W. Gibbons, and R. Cheney. Terrestrial habitat use by aquatic turtles of Carolina bays: Implications for upland habitat conservation. Society for the Study of Amphibians and Reptiles. Boone, NC. August 1995.

Burrows, Dr. R. **Invited Speaker.** Quality metrics for a small research organization. Trade Quality Management Conference. Baltimore, Maryland. May 1996.

Chesser, R. K. **Invited Speaker.** The ecological and sociological effects of the Chernobyl disaster. The University of Idaho. Moscow, ID. September 1995.

Chlopecka, A. and D.C. Adriano. Influence of a by-product Fe-Oxiole on mobility and plant uptake of metals. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. St. Louis, MO. October 1995.

Clark, S.B. and G.R. Choppin. **Invited Speaker.** A comparison of *f*-element dissociation kinetics from synthetic polyelectrolytes and humic acid. American Chemical Society. Chicago, IL. August 1995.

Clark, S.B., S.M. Serkiz, and W.H. Johnson. **Poster.** Uranium partitioning in natural systems under acidic conditions: A comparison of laboratory and field data. MIGRATION 95. St. Malo, France. September 1995.

Clark, S.B., A.G. Sowder, R.A. Fjeld. Transformation kinetics and solubility of uranium mineral phases in phosphate and silicate media. MIGRATION 97. St. Malo, France. September 1995.

Clark, S.B., W.H. Johnson, S.M. Serkiz, T.G. Hinton, and M. Malek. **Invited Speaker.** An evaluation of sequential extraction procedures to estimate geochemical controls on the mobility of fission products and actinide contaminants in soil fractions of natural systems. MIGRATION 97. St. Malo, France. September 1995.

Clark. S.B. **Invited Speaker.** Environmental Radiochemistry in 2020. 1995 International Chemical Congress of Pacific Basin Societies. Honolulu, Hawaii. December 1995.

Collins, B.S. and G.R. Wein. Oldfield response to frequency and intensity of disturbance. Ecological Society of America. Snowbird, UT. August 1995.

Collins B.S. and G.R. Wein. Effects of soil resource heterogeneity of early old field succession. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Congdon, J.D. **Invited Speaker.** Delayed sexual maturity. Georgia Southern University. Statesboro, GA. February 1996.

Congdon, J.D. **Invited Speaker.** Evolution of delayed sexual maturity. Eastern Illinois University. Charleston, IL. April 1996.

Congdon, J.D. **Invited Speaker.** Delayed sexual maturity. Auburn University. Auburn, AL. May 1996.

Congdon, J.D. **Invited Speaker.** Dr. Donald W. Tinkle Lecture: Evolution of longevity. Museum of Zoology. University of Michigan. Ann Arbor, MI. April 1996.

Conner, W.H., K.W. McLeod, and J.K. McCarron. Response of forested wetland species to increased flow and salinity. Estuarine Research Federation. Corpus Christi, TX. November 1995.

Consolie, P., I.L. Brisbin, Jr., and R.A. Kennamer. **Poster.** ^{137}Cs levels in wintering American coots during the refill of a partially drained contaminated reactor-cooling reservoir. The Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Dixon, P.M. **Invited Speaker.** Statistical analysis of upper boundaries. Using ecological relevant statistics. Miami University. Oxford, OH. October 1995.

Dixon, P.M. Spatial patterns and their consequences in deciduous forests. Miami University. Oxford, OH. October 1995.

Dixon, P.M. **Invited Speaker.** Using ecologically relevant statistics. Virginia Polytechnical Institute. Blacksburg, VA. October 1995.

Dorcas, M.E., C.R. Peterson, and M.E. Flint. The thermal biology of digestion in rubber boas (*Charina bottae*): Physiology, behavior, and environmental constraints. Society for the Study of Amphibians and Reptiles. Boone, NC. August 1995.

Dorcas, M.E., C.R. Peterson, T. Tuberville, R. Nagle, J.W. Gibbons, and J.D. Congdon. Using automated recording systems to monitor anuran populations on the Savannah River Site. North

automated recording systems to monitor anuran populations on the Savannah River Site. North American Amphibian Monitoring Program and Task Force. Burlington, Ontario, Canada. September 1995.

Edwards, A. L., R.R. Sharitz, and J.L. Hamrick. Population genetic structure of the rare *Sagittaria isoetiformis*. Southeastern Population Ecology and Genetics Group. Highlands, NC. October 1995.

Edwards, A.L. Population genetics of the rare *Sagittaria isoetiformis* (Alismataceae): Surprising preliminaries. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Fletcher, D.E., G.K. Meffe, and S.D. Wilkins. **Invited Speaker.** Fish communities in upper coastal plain stream after 35 years of nuclear effluent discharges: Patterns and paradoxes. American Fisheries Society. Tampa, FL. August 1995.

Ford, R.G. and P.M. Bertsch. Divalent metal interactions with ferrihydrite: Crystallization to substituted goethite and hematite. National meeting of the Materials Research Society. San Francisco, CA. April 1996.

Ford, R.G. and P.M. Bertsch. Changes in divalent metal partitioning during iron (HYDR) oxide aging. Annual Meeting of the Clay Minerals Society. Gatlinburg, TN. June 1996.

Frazer, N.B., J.I. Richardson, and J.D. Congdon. High survival rates for nesting hawksbills: Implications for conservation. 16th Annual Symposium on Sea Turtle biology and Conservation. Hilton Head, SC. February 1996.

Gaiser, E.E. and B.E. Taylor. Development of a diatom training set for the reconstruction of hydrologies in Carolina bays of the Upper Atlantic Coastal Plain. North American Diatom Symposium. Milford, IA. September 1995.

Gaiser, E.E. and B.E. Taylor. Paleolimnological reconstruction of Holocene environments. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Gaiser, E.E. Distribution of diatoms along hydrologic gradients within and among Carolina bays of the Upper Atlantic Coastal Plain. Southeastern Phycological Colloquium. Charleston, SC. October 1995.

Garrett, K.A. and P.M. Dixon. Higher order interactions among spatially mapped individuals: An interactive approach. Society for the Study of Evolution. Montreal, Quebec, 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. August 1995.

Gates, W.P., B.J. Teppen, and P.M. Bertsch. The orientation of TMPA in the interlayer space of

smectites. Clay Mineral Society. Gatlinburg, TN. June 1996.

Gibbons, J.W. **Invited Speaker.** Reptiles and amphibians of Alabama. Audubon Society. Tuscaloosa, AL, September 1995.

Gibbons, J.W. Reptiles and amphibians of Alabama. Arcadia School. Tuscaloosa, AL, September 1995.

Gibbons, J.W. **Invited Speaker**. Wildlife of the CSRA. International Canal Association. Augusta, GA. October 1995.

Gibbons, J.W. **Invited Speaker.** Conservation from a herpetological perspective. Conservation Biology Graduate Seminar, Institute of Ecology, University of Georgia. Athens, GA. October 1995.

Gibbons, J.W. Reptiles and amphibians. Mitchell County Middle School, Camilla, GA. November 1995.

Gibbons, J.W. Biodiversity: Prospect and promise for the SRS. Sigma XI: The Central Savannah River Area Chapter. Augusta, GA. December 1995.

Gibbons, J.W. Student Environmental Forum. South Carolina Environmental Education Consortium, Francis Marion University. Florence, SC. January 1996.

Gibbons, J.W. Reptiles and amphibians of Georgia. Georgia Herpetological Society. Conyers, GA. January 1996.

Gibbons, J.W. Hidden herpetofaunal biodiversity of the Low Country. The Nature Conservancy's 1996 International Conference. Savannah, GA. January 1996.

Gibbons, J.W. **Invited Speaker**. Get to know your neighbors: Reptiles and amphibians of South Carolina. The Student Club. Aiken, SC. February 1996.

Gibbons, J.W. Keeping all the pieces. Biology 108 Honors Club, University of Georgia. Athens, GA. February 1996.

Gibbons, J.W. Reptiles and amphibians of the CSRA. St. Mary's Elementary School. Augusta, GA. February 1996.

Gibbons, J.W. From fresh water to the sea: The turtle bridge is complete. Sea Turtle Symposium, Hilton Head, SC. February 1996.

Gibbons, J.W. Reptile and amphibian workshop. SREL. Aiken, SC. March 1996.

Gibbons, J.W. Get to know your neighbors reptiles and amphibians of South Carolina. Morning Enrichment Program, Millbrook Elementary School, Aiken, SC. March 1996.

Gibbons, J.W. **Invited Speaker.** Reptile and amphibian study. Boy Scout Salkehatchie District Camporee. Blackville, SC. March 1996.

Gibbons, J.W. **Invited Speaker**. Sherman's march through herpetology; as told by a Southerner. Sherman A. Minton Symposium. Indianapolis, IN. April 1996.

Gibbons, J.W. Biodiversity of Georgia: Reptiles and amphibians. Elderhostel, Georgia College. Milledgeville, GA. April 1996.

Gibbons, J.W. **Invited Speaker** Reptile biodiversity of South Carolina forests. Association of Consulting Foresters, S. C. Chapter. Aiken, SC. April 1996.

Gibbons, J.W. Snake safety. South Carolina Electric and Gas Co. Langley, SC. May 1996.

Gibbons, J.W. Reptiles and amphibians. Monroe Primary School. Monroe, GA. May 1996.

Gibbons, J.W. Reptiles and amphibians: Alabama's natural heritage. Hillcrest High School., Tuscaloosa, AL. May 1996.

Gibbons, J.W. Reptiles and amphibians of South Carolina. Sand River Woman's Club. Aiken, SC. May 1996.Gibbons, J.W. Reptiles and amphibians. Mead Hall. Aiken, SC. May 1996.

Grant, J.A., M.J. Brooks, and B.E. Taylor. **Invited Speaker.** Unraveling the evolution of enigmatic Carolina bays. American Association for the Advancement of Science. Baltimore, MD. February 1996.

Greene, D. and M.C. Newman. **Poster.** UNCENSOR V4.0. Estimation of univariate statistics for censored data sets. The Society of Environmental Toxicology and Chemistry Conference. Vancouver, British Columbia. Canada. November 1995.

Gubista, K.R. Population decline of *Peromyscus leucopus*: Effect of decreasing food resource availability on reproductive biology. Ecological Society of America. Snowbird, Utah. August 1995.

Gubista, K.R., H.P. Liu, C. Schmidt, and R.K. Chesser. Genetic variation of white-footed mice, *Peromyscus leucopus*, using microsatellite DNA: A preliminary report. Southeastern Population Ecology and Genetics Group Meeting. Highlands, NC. October 1995.

Hicks, K.D. Rostal, D. Jones, and M.E. Mulvey. Allozymic variation in populations of *Gopherus polyphemus*. Society for the Study of Amphibians and Reptiles. Appalachian State University. Boone, NC. August 1995.

Hill A.B., C.H. Jagoe and P.V. Winger. **Poster**. Mercury in alligators and racoons from the Okefenokee Swamp. Carolinas Chapter, Society of Environmental Toxicology and Chemistry. Hunterville, NC. April 1996.

Hinton, T.G., M. Malek, Y. Ivanov, M. McDonald, and N. Arkipov. **Poster.** Foliar absorption of resuspended ^{90}Sr and ^{137}Cs relative to other pathways of plant contamination. Swedish Radiation Protection Institute and the Atomic Energy. Stockholm, Sweden. May 1996.

Hunter, D.B., K.M. Kemner, W.T. Eam, and P.M. Bertsch. Extended X-Ray absorption fine structure studies of Cs-dibenzo-18-crown-6 either complexes. American Chemical Society. Chicago, IL. August 1995.

Imm, D.W., B.S. Collins, and W.P. Smith. Simulated effect of opening size and shape on woody seedling establishment. Ecological Society of America. Snowbird, UT. August 1996.

Imm, D.W., K.W. McLeod, and B.P. Moyer. Natural and anthropogenic patterns of composition and species diversity of forests of the Savannah River Site. Botanical Society of America. San Diego, CA. August 1995.

Jagoe, C.H., and R. Pickens. **Poster.** Relationships between precipitation and surface water chemistry in three Carolina bays. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Jagoe, C.H, C. McCreedy, L. Glickman, and I.L. Brisbin, Jr. Patterns of ^{137}Cs accumulation in bullhead catfish inhabiting an abandoned reactor reservoir. The Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia Canada. November 1995.

Jagoe, C.H., C. Salice, B. Grasman, and T. Youngblood. Effects of drawdown of a reservoir on mercury content of largemouth bass and other biota. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Jagoe, R. H, and M.C. Newman. **Poster**. Bootstrap estimation of community NOEC values. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Jagoe, C.H., P. Shaw-Allen, and S. Brundage. **Poster.** Tissue mercury and gill Na, K, and ATPase activity in largemouth bass from three reservoirs with different levels of mercury contamination. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Jagoe, R.H., and M.C. Newman. **Poster.** Resampling estimation of community-level NOEC. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Jagoe, C., P. Shaw-Allen, G. Yanochko, B. Arnold-Hill, and I.L. Brisbin, Jr. **Poster**. Studies of

mercury contamination in aquatic systems on the Savannah River Site in South Carolina. Southeastern U.S. Mercury Conference. Miami, FL. February 1996.

Johns, P.E., J. Novak, and M.H. Smith. Analysis of car-deer accidents on the Savannah River Site. Southeastern Section of the Wildlife Society and Florida Chapter's 19th Annual Southeast Deer Study Group Meeting. Orlando, FL. February 1996.

Kandl, K.L. **Invited Speaker.** Demographic and genetic consequences of chronic environmental stress of eastern mosquitofish populations. Ecological Society of America. Snowbird, UT. August 1995.

Kandl, K.L. Salinity and inbreeding stress: Effects on population dynamics of the eastern mosquitofish, *Gambusia holbrooki*. Southeastern Population Genetics and Ecology Group. Highlands, NC. October 1995.

Karapatakis, D., T.E. Rea, J.E. Pinder III, and H.E. Mackey. Bathymetry as a controlling factor in macrophyte development: Thirty years of change detection in a former reactor cooling pond. Association of Southeastern Biologists. Statesboro, GA. April 1996.

King, C.J. and R.R. Sharitz. Reinvasion of woody vegetation into a severely impacted area of floodplain forest. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Koetsier, P. and J V. McArthur. The Effects of *Sparganium americanum* beds on organic matter retention and storage in two Southeastern blackwater streams (South Carolina, USA). Kalispel, MT. June 1996.

Lee, J.R. Patterns of winter activity in *Nerodia* spp. in an outdoor enclosure. Society for the Study of Amphibians and Reptiles. Boone, NC. August 1995.

Lee, J.R. **Invited Speaker.** Body temperature variation in overwintering cottonmouths: active selection or environmental constraint. Pocatello, Idaho. May 1996.

Lee, J.R. Movement patterns of the cottonmouth, *Agkistrodon piscivorus*. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Lide, R.F. Carolina bay hydrology: A view from the Upper Coastal Plain of Western South Carolina. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Lide, R.F., L.K. Kirkman, and G.R. Wein. **Poster.** Land cover change in Carolina bays and similar depression wetlands at the Savannah River Site. South Carolina: 1951-1992. Ecological Society of America. Snowbird, UT. August 1995.

Liu, H.P. and J.B. Mitton. Paternal mitochondrial DNA differentiation far exceeds maternal

mitochondrial DNA and allozyme differentiation in the freshwater mussel, *Anodontia grandis grandis*. Society of Systematic Biologists, Society for the Study of Evolution, the American Society of Naturalist and the 27th International Numerical Taxonomy Conference. Montreal, Quebec Canada. July 1995

Liu, H.P. **Invited Speaker.** Freshwater mussel, *Pyganodon grandis*. Taiwan Normal University. Typie, Taiwan. March 1996.

Liu, H.P. **Invited Speaker.** Gender-specific mitochondrial DNA within and among populations of the freshwater mussel, *Pyganodon grandis*. Academia Sinica, Institute of Zoology. Nankang, Taiwan. March 1996.

McArthur, J V. **Invited Speaker.** Physiologic and genetic determinants of lotic bacterial distribution and abundance. Society of International Limnology. Saõ Paulo, Brazil. July 1995.

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

McCarron, J.K. and K.W. McLeod. Effects of salinity stress on bald cypress (*Taxodium distichum)* in saturated and unsaturated soils. Association of Southeastern Biologists. Statesboro, GA. April 1996.

McCloskey, J.T., M.C. Newman, and S.B. Clark. Predicting the toxicity of metals to bacteria (Microtox®) using Ion characteristics. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

McCreedy, C.D., C.H. Jagoe, C.E. Dallas, I.L. Brisbin, Jr. and R. Wentworth. **Poster.** Quality Control in the application of flow cytometric assays of genetic damage due to environmental contaminants. The Society of Environmental Toxicology Chemistry. Vancouver, British Columbia, Canada. November 1995.

McLeod, K.W. and M.R. Reed. Influence of an existing willow canopy on restoration of wetland forest. Association of Southeastern Biologists. Statesboro, GA. April 1996.

McLeod, K.W. and M.R. Reed. Influence of an existing willow canopy on restoration of wetland forests. Society of Wetland Scientists. Kansas City, MO. June 1996.

McLeod, K.W., J.K. McCarron, and W.H. Conner. Effects of inundation and salinity on four bottomland oak species. Ecological Society of America. Snowbird, UT. August 1995.

Meffe, G.K. Elements of and threats to biodiversity. Bureau of Land Management, Training Symposium of Adaptive Management for Biodiversity. LaCross, WI. August 1995.

Meffe, G.K. Sustainable Development: Conservation panacea or politically correct ecocide. Aldo Leopold Shack Foundation. Baraboo, WI. August 1995.

Meffe, G.K. Biodiversity, habitat alteration, and endangered species: Common ground in business and environment. University of South Carolina, Masters Program in International Business. Columbia, SC. September 1995.

Meffe, G.K. An Approach to ecosystem conservation. U.S. Fish and Wildlife Service Training Course. Vancouver, WA. September 1995.

Meffe G.K. Applying the principles of conservation biology to restoration. 57th Midwest Fish and Wildlife Conference. Detroit, MI. December 1995.

Meffe, G.K. Scientists in conservation: A creative tension. Environmental Quality Workshop. American Society of Ichthyologists and Herpetologists. New Orleans, Louisiana. June 1996.

Megonigal, J.P., W.H. Conner, S. Kroeger, and R.R. Sharitz. Abovegournd production in Southeastern floodplain forests: A test of the subsidy-stress hypothesis. Southern Forested Wetlands Ecology and Management. Clemson University. Clemson, SC. March 1996

Miller, S. The effect of flooding on mycorrhizal infection of two grasses in P-limited wetlands. Fourth symposium on Biogeochemistry of Wetlands. New Orleans, LA. March 1996.

Miller, S.P. and R.R. Sharitz. Patterns of VA-mycorrhizal infection in two grasses along a hydrochemical gradient. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Mills, M. S. Weight loss and other costs of winter activity in brown water snakes. Society for the Study of Amphibians and Reptiles. Boone, NC. August 1995.

Mills, G.L., G. Voos, J. O'Neill, and W.A. Jones. The use of molecular marker compounds as an index of petroleum degradation. American Chemical Society. Atlanta, GA. September 1995.

Mills, G.L., G. Voos, J. O'Neill, and W.A. Jones. Assessment of the use of molecular marker compound as an index of the biodegradation of diesel fuel hydrocarbons in soil. American Chemical Society. New Orleans, LA. March 1996.

Mills, G.L. Subsurface transport and bioremediation of diesel fuel hydrocarbons in terrestrial systems. Medical University of South Carolina. Charleston, SC. April 1996.

Mills, G.L. Bioremediation of diesel fuel hydrocarbons in soils. Clafin College. Orangeburg, SC. April 1996.

Mills, M.S. Winter activity and movement patterns in the brown water snake, *Nerodia taxispilota*.

Association of Southeastern Biologists. Statesboro, GA. April 1996.

Mills, G.L. **Invited Speaker.** Application of molecular markers for assessing bioremediation of diesel fuel hydrocarbons. Department of Geology, University of Georgia. Athens, GA. June 1996.

Mulvey, M.E. **Invited Speaker.** The genetics and conservation of freshwater mussels. Biology Department, Georgia Southern University. Statesboro, GA. January 1996.

Newman, M.C. and M.E. Mulvey. **Poster.** *Helix aspersa* lead exposure history and possible adaption: Shell composition, conchology and genetics. American Malacological Union Meetings, Hilo, HI. June 1995.

Newman, M.C. and J.T. McCloskey, Jr. Predicting intermetal trends in bioactivity: Microdots bioassay. The Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Novak, J.M. and J.P. Krenz. Morphological asymmetry and ecological toxicology in cotton rats. Society for Study of Evolution. St. Louis, MO. June 1996.

Nussele, P.R., W.P. Gates, D.B. Hunter, and P. M. Bertsch. **Poster.** An In situ XANES and FTIR study of surface-enhanced reduction of smectite structural Fe by organoborates. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. St. Louis, MO. November 1995.

Pauley, E.F., B.P. Allen, M.B. Dietsch, and R.R. Sharitz. Post-hurricane dynamics in bottomland hardwood forests of the Congaree Swamp National Monument, South Carolina. Ecological Society of America. Snowbird, UT. August 1995.

Pauley, E.F., B.S. Collins, and W.P. Smith. Vegetation response to gap creation in a bottomland hardwood forest. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Pauley, E.F., B.S. Collins, and W.P. Smith. Early establishment of cherrybark oak in bottomland hardwood gaps: Effects of seed predation, gap size, herbivory, and competition. Southern Forested Wetlands Ecology and Management Conference. Clemson, SC. March 1996.

Pechmann, J. H., R.D. Semlitsch, D.E. Scott, and J.W. Gibbons. Predation, competition, and disturbance in a natural amphibian community over 16 years. Ecological Society of America. Snowbird, UT. August 1995.

Pechmann, J.H. **Invited Speaker.** Population regulation in species with complex life cycles: An experimental approach with amphibians. Department of Biology. College of Charleston. Charleston, SC. April 1996

Pechmann, J.H. **Invited Speaker.** Population regulation in species with complex life cycles: An experimental approach. Department of Zoology and Wildlife Science, Auburn University. Auburn, AL. May 1996.

Pinder J.E., III, E.M. Jahnke, and T.E. Rea. Sherman's march to the sea: Using satellite images to examine potential residual impacts on the Georgia landscape. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Pinder, J.E.,III, E.M. Jahnke, and T.E. Rea. Sherman's march to the sea: Using satellite images to examine residual impacts on the Georgia landscape. American Society for Photogrammetry and Remote Sensing. Baltimore, MD. April 1996.

Philippi, T.E. and Dixon P.M. Initial steps toward a method of analyzing vegetation samples including vegetation change. Ecological Society of America. Snowbird, UT. August 1995.

Philippi, T.E. Detecting trends in species composition. Sustainable Biosphere Initiative. Washington, DC. May 1996.

Rea, T.E, D. J. Karapatakis, J.E. Pinder III, and H.E. Mackey Jr. Bathymetry as a controlling factor in macrophyte development: Thirty years of change detection in a former reactor cooling pond. American Society for Photogrammetry and Remote Sensing. Balitmore, MD. April 1996.

Romanek, C.S., K. Thomas, E. Gibson, D. Mckay, and R. Socki. Carbon-and sulfur-bearing minerals in the Martian meteorite Allan Hills 84001. Meteoritical Society. Washington, D.C. September 1995.

Romanek, C.S. **Poster.** Molecular and isotopic analysis of volatiles derived from laser interactions with solid surfaces. 36th Oak Ridge National Laboratory (ORNL)-DOE Conference on Analytical Chemistry in Energy Technology. Gatlinburg, TN. October 1995.

Romanek, C.S., C. Perry, R.A.,Sock, and E.K. Gibson. Stable isotope analysis of diatomic oxygen gas from quartz. Geological Society of America. New Orleans, LA. November 1995.

Romanek, C.S. Stable isotopes in groundwater studies. University of Charleston, Department of Geology. Charleston, S. C. November 1995.

Romanek, C.S. **Poster.** Cryogenic weathering as a mechanism for stable isotope enrichment in soil carbonate from Wright Valley, Antarctica. Geological Society of America. New Orleans, La. November 1995.

Rowe, C., O. Kinney, A. Fiori, and J. Congdon. Pollution-related oral deformities in tadpoles of the bullfrog: effects on grazing ability and growth. American Society of Ichthyologists and Herpetologists. New Orleans, LA. June 1996.

Schultz, I.R., M.C. Newman, E.L. Peters. **Poster.** Toxicokinetics and disposition of inorganic mercury and cadmium in channel catfish after intravascular injection. Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

Serkiz, S.M.,Clark S.B., and W.H. Johnson. **Poster.** Uranium partitioning in natural systems under acidic conditions: A comparison of laboratory and field data. MIGRATION 95. St. Malo, France. September 1995.

Scott, D. and S. Doody. Effect of flooding date on hatchling characteristics of *Ambystoma opacum*. Society for Study of Amphibian and Reptiles. Appalachian State University. Boone, NC. August 1995.

Seaman, J.C. and P.M. Bertsch. Retardation of fluorobenzoate tracers in highly weathered soils and sediments. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. St. Louis, MO. November 1995.

Seaman, J.C., L. Schunille, P.M. Bertsch, and W.J. Walker, reclamation of Cr (VI) contaminated soils and aquifer sediments. American Geophysical Union. San Francisco, CA. December 1995.

Seaman, J.C. and P.M. Bertsch. **Poster.** ACCES and selective colloid mobilization technology. International Business Communications. Arlington, VA. May 1996.

Seaman, J.C. and P.M. Bertsch. Characterizing mobile soil and ground-water colloids. Clay Minerals Society. Gatlinburg, TN. June 1996.

Seaman, J.C. and P.M. Bertsch. Selective colloid mobilization in aquifers via an in situ surface chemical manipulation technology. Clay Minerals Society. Gatlinburg, TN. June 1996.

Seaman, J.C., E.J. Gall, L. Schwallie, D.B. Hunter, and P.M. Bertsch. Remediation of Cr(VI) contaminated soils and aquifers using Fe(II) solutions. Clay Minerals Society. Gatlinburg, TN. June 1996.

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. August 1995.

Sharitz, R.R. **Invited Speaker.** Pocosins and Carolina bays. Southern Forested Wetlands Ecology and Management Symposium. Clemson University. Clemson, SC. March 1996.

Sharitz, R. R. **Plenary Address.** An experiment in community involvement: Conservation and management in the Edisto River Basin. Graduate Student Research Symposium, Institute of Ecology, University of Georgia. Athens, GA. January 1996.

Sharitz, R. R. The Edisto River Basin study: Is this a model for ecosystem management? Savannah River Ecology Laboratory. Aiken, SC. February 1996.

Sharitz, R. R. **Invited Speaker**. Evaluation and conservation of the river environment. International Workshop on Environmental Problems. Japanese Center for International Studies in Ecology, Yokohama, Japan. May 1996.

Sharitz, R. R. Restoration of riparian wetlands. International Relay Symposium on Preservation and regeneration of the natural environment. Matsuyama, Japan. June 1996.

Sharitz, R. R. Preserving wetland values. Yamanishi Environmental Forum. Kofu, Japan. June 1996.

Shealy, H.E., and R.R. Sharitz. GIS evaluation of wetlands of the Edisto River basin in South Carolina. Southern Forested Wetlands Ecology and Management Symposium. Clemson University. Clemson, SC. March 1996

Shealy, H.E. and R.R. Sharitz. GIS evaluation of wetlands of the Edisto River Basin in South Carolina. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Sherony, C., D.C. Adriano, and J. Albright. Remediation of radionuclide contaminated soils. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. St. Louis, MO. November 1995.

Singer, J.H. and R.R. Sharitz. Herbaceous vegetation responses to restoration treatments in a Carolina bay wetland. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Smith, M.H., I.L. Brisbin, Jr., and R.A. Kennamer. Lessons learned from 25 years of genetic research on natural vertebrate populations. National Conference on Wildlife Forensics. Medford, OR. October 1995.

Smith, M.H. **Invited Speaker.** Lessons learned from 25 years of genetic research on natural vertebrate populations. San Diego State University. San Diego., CA. October 1995.

Smith, M.H. and J.R. Purdue. Spatial heterogeneity in haploid mt DNA and diploid nuclear genetic markers in a white-tail deer herd. American Society of Mammalogists. Grand Forks, N.D. June 1996.

Stockwell, C.A. and M.E. Mulvey. Preserving allelic diversity: are translocations successful? Society for the Study of Evolution. Montreal, Quebec, Canada. July 1995.

Stockwell, C.A., Evolutionary trajectories in translocated populations: Tinkering with evolution? Desert Fishes Council. Reno, NV. 1995.

Stockwell, C.A. S.C. Weeks, and G.C. Meffe. Life history variation in recently established populations of mosquitofish: A case of rapid evolution? Ecological Society of America. Snowbird, UT. August 1995.

Stockwell, C.A. and M.E. Mulvey. Report to White Sands pupfish conservation team. Holloman

Airforce Base. Alncogordo, NM. March 1996.

Sugg, D.W. Loss and apportionment of genetic variation in socially structured populations. Department of Zoology and Wildlife Ecology, Auburn University. February 1996.

Sugg, D.W. Population genetics meets Behavioral ecology. Department of Biology, State University of New York--Geneseo. March 1996.

Sugg, D.W. Population genetics meets behavioral ecology. Savannah River Ecology Laboratory. Aiken, SC. May 1996.

Sugg, D.W. Effective population size and the assumption of random mating. American Society of Mammalogists. June 1996.

Taylor, B.E. and M.J. Brook. Predictability of water level in a Carolina bay: A baseline for interpreting the activities of modern copepods and prehistoric humans. Ecological Society of America. Snowbird, UT. August 1995.

Teppen, B.J, D.B. Hunter, P.M. Bertsch, E.J. Sullivan, and R.S. Bowman. **Poster.** Modeling organic modification of a natural zeolite surface. American Chemical Society. Chicago, IL. August 1995.

Teppen, B.J. Molecular dynamics simulations of clay minerals and clay-solution interfaces. Minerals Technology Research Group, English China Clays International. Sandersville, GA. August 1995.

Teppen, B.J. Molecular simulations of aqueous cation adsorption to mineral surfaces. Soil Science Society of America. St. Louis, MO. October 1995.

Teppen, B.J. **Poster.** A valence force field for molecular dynamics of dioctahedral clays. Clay Minerals Society. Gatlinburg. TN. June 1996.

Tidd, S., J.E. Pinder III, and G. Ferguson. Long-term habitat analysis of *Pyxis planicanda* using remote sensing. International Herpetological Symposium. San Antonio, TX. June 1996.

Tuberville, T.D. Invasion of new aquatic habitats by male freshwater turtles. Association of Southeastern Biologists. Statesboro, GA. April 1996.

Uhal, H., Serkiz, S.M., Johnson, L.M., S.B. Clark, and A.L. Bryce. Sorption of uranium in a system containing kaolinite and natural organic matter: A comparison of model and laboratory results. American Chemical Society. New Orleans, LA. March 1996.

Voos, G., G.L. Mills, J. O'Neill, and W. Jones. The use of molecular marker compounds as an index of petroleum degradation. American Chemical Society. Atlanta, GA. September 1995.

Weber, J., J. Gariboldi, and D.C. Adriano. High application rates of coal ash in sod farms may

enhance soil-plant-water relations. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. St. Louis, MO. November 1995.

Whiteman, H. **Invited Speaker.** Alternative strategies in evolutionary biology. Western State College. Gunnison, CO. October 1995.

Whiteman, H. **Invited Speaker.** Evolution of alternative life histories in salamanders. Division of Biological Science, University of Missouri. Columbia, MO. October 1995.

Whiteman, H. **Invited Speaker.** Amphibian decline: Science or speculation? Randolph-Macon College. Ashland, VA. February 1996.

Wise, M.G., J V. McArthur, and L.J. Shimkets. The microbial diversity of a Carolina bay as determined by 16s rRNA gene cloning and sequencing. American Society of Microbiology. New Orleans. May 1996.

Wise, M.G., J V. McArthur, and L.J. Shimkets. Genetic structure of a population of lotic bacteria. Southeastern Regional American Society Microbiology. Birmingham, AL. November 1995.

Woodward, L.A. **Poster.** Fluctuating asymmetry as a measure of mercury effect on chironomids. The Society of Environmental Toxicology and Chemistry. Vancouver, British Columbia, Canada. November 1995.

IV. SREL EDUCATION PROGRAM
August 1995-July 1996

Undergraduate Research Participation Program

Natashia Bush	University of South Carolina, Aiken, SC	Dr. J Vaun McArthur
Jay Clark	Erskine College, Due West, SC	Dr. I. Lehr Brisbin
Daniel Connor	Georgia Tech University, Atlanta, GA	Dr. Tom Hinton
Raymond Danker	Clemson University, Clemson, SC	Dr. Domy Adriano
Ronnie Devine	South Carolina State University, Orangeburg, SC	Dr. Beverly Collins
Alison Fiori	Duke University, Durham, NC	Dr. Justin Congdon
Joshua Ford	St. Lawrence University, Canton, NY	Dr. Rebecca R. Sharitz
Jimmy Hill	Clemson University, Clemson, SC	Dr. J. Whitfield Gibbons
Ethan Jahnke	Colorado State University, Fort Collins, CO	Dr. John Pinder
Owen Kinney	Berry College, Rome, GA	Dr. Justin Congdon
Katie Kurkjian	University of Georgia, Athens, GA	Dr. Ron Chesser
Angela Lueking	University of Nebraska, Lincoln, NE	Dr. Sue Clark
Alison Moulding	Duke University, Durham, NC	Dr. J. Whitfield Gibbons
Beth Newbold	Wofford College, Spartansburg, SC	David Scott
Jeannine Ott	University of Georgia, Athens, GA	Dr. J. Whitfield Gibbons
Kevin Palmer	Georgia Southern University, Statesboro, GA	Dr. Peg Mulvey
Christine Rabideau	St. Michael's College, Colchester, VT	Dr. Chuck 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

TRAC (Teacher Research Associates)

Steven Clasen	Monument Valley High School, Kayenta, AZ	Dr. John E. Pinder III
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/Tony Mills
Kathryn Komoroski	Athens Montessori Middle School, Athens, GA	Dr. Justin Congdon

HIGH SCHOOL RESEARCH PARTICIPATION PROGRAM

William Moretz	Augusta Preparatory Day School, Augusta, GA	Dr. J. Whitfield Gibbons

HIGH SCHOOL DOE INTERNS

Naveen Pogula	Lakeside High School, Evans, GA	Dr. Beverly Collins

SCUREF Scholars (South Carolina Universities Research and Education Foundation)

John Bradford,III	Clemson University, Clemson, SC	Dr. Domy Adriano
Betsy Gerwig	Clemson University, Clemson, SC	Dr. Domy Adriano

GRADUATE RESEARCH PARTICIPATION PROGRAM

Joe Albright	Ph.D.	University of Georgia, Athens, GA	Dr. Domy Adriano
Christopher Beck	Ph.D.	University of Georgia, Athens, GA	Dr. Justin Congdon
Jennifer Brofft	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Kurt Buhlmann	Ph.D.	University of Georgia, Athens, GA	Dr. J. Whitfield 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
Kevin Holloman	Ph.D.	University of Georgia, Athens, GA	Dr. Ron Chesser

John Kind	Ph.D.	University of Georgia, Athens, GA	Dr. Ron Chesser
Mark Komoroski	M.S.	University of Georgia, Athens, GA	Dr. Justin Congdon
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. J. Whitfield Gibbons
Jennifer Olson	M.S.	Texas A&M University, College Station, TX	Dr. Gary Mills
Melissa Pilgrim	M.S.	Southeastern Louisiana University	Dr. J. Whitfield Gibbons
Gordon Plague	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Pamela Schultz	M.S.	University of Georgia, Athens, GA	Dr. Gary Mills
Michael Schwartz	Ph.D.	University of Georgia, Athens, GA	Dr. J. Whitfield Gibbons
Julian Singer	M.S.	University of Georgia, Athens, GA	Dr. Rebecca R. Sharitz
Susan Stibbe	M.S.	University of Georgia, Athens, GA	Dr. J Vaun McArthur
Chris 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
Rebecca Yeomans	Ph.D.	University of Georgia, Athens, GA	Dr. Justin Congdon

DOE LABORATORY GRADUATE FELLOWSHIPS

Loretta Battaglia	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca R. Sharitz
Michael Draney	Ph.D.	University of Georgia, Athens, GA	Dr. Barbara Taylor
Adrienne Edwards	Ph.D.	University of Georgia, Athens, GA	Dr. Rebecca R. Sharitz
Aissa Feldmann	M.S.	University of Georgia, Athens, GA	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
Chris Harrison	Ph.D.	Texas A&M University, College Station, TX	Dr. J. Whitfield Gibbons
John Lee	M.S.	University of Georgia, Athens, GA	Dr. J. Whitfield 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
LeeAnn Woodward	Ph.D.	University of California, Davis, CA	Dr. Michael Newman

SREL Graduate Students Completing Degree Requirements

Vincent James Burke. 1995. Ecological and Conservation Implications of Terrestrial Habitat use by Aquatic Turtles. Doctor of Philosophy, University of Georgia.

Aissa Louise Feldmann. 1996. The Effects of Beaver *Castor canadensis* Impoundment on Plant diversity and Community Composition in the Coastal Plain of South Carolina. Master of Science, University of Georgia.

Kathryn Rose Gubista. 1995. *Peromnyscus* Population Decline; Genetic, Morphological and Life History Variation. Doctor of Philosophy, University of Georgia.

Karen Lynn Kandl. 1996. Interaction of Inbreeding and Salinity Stress: Effects on Individual Survival and Dynamics of Experimental Populations of Eastern Mosquitofish *Gambusia holbrooki*. Doctor of Philosophy, University of Georgia.

Mark Komoroski. 1996. A Comparative Analysis of Amphibian Egg Lipids. Master of Science, University of Georgia.

H. Justin Mohler. 1996. Temporal Trends of ^{137}Cs in an Abandoned Reactor Cooling Reservoir. Master of Science. Colorado State University.

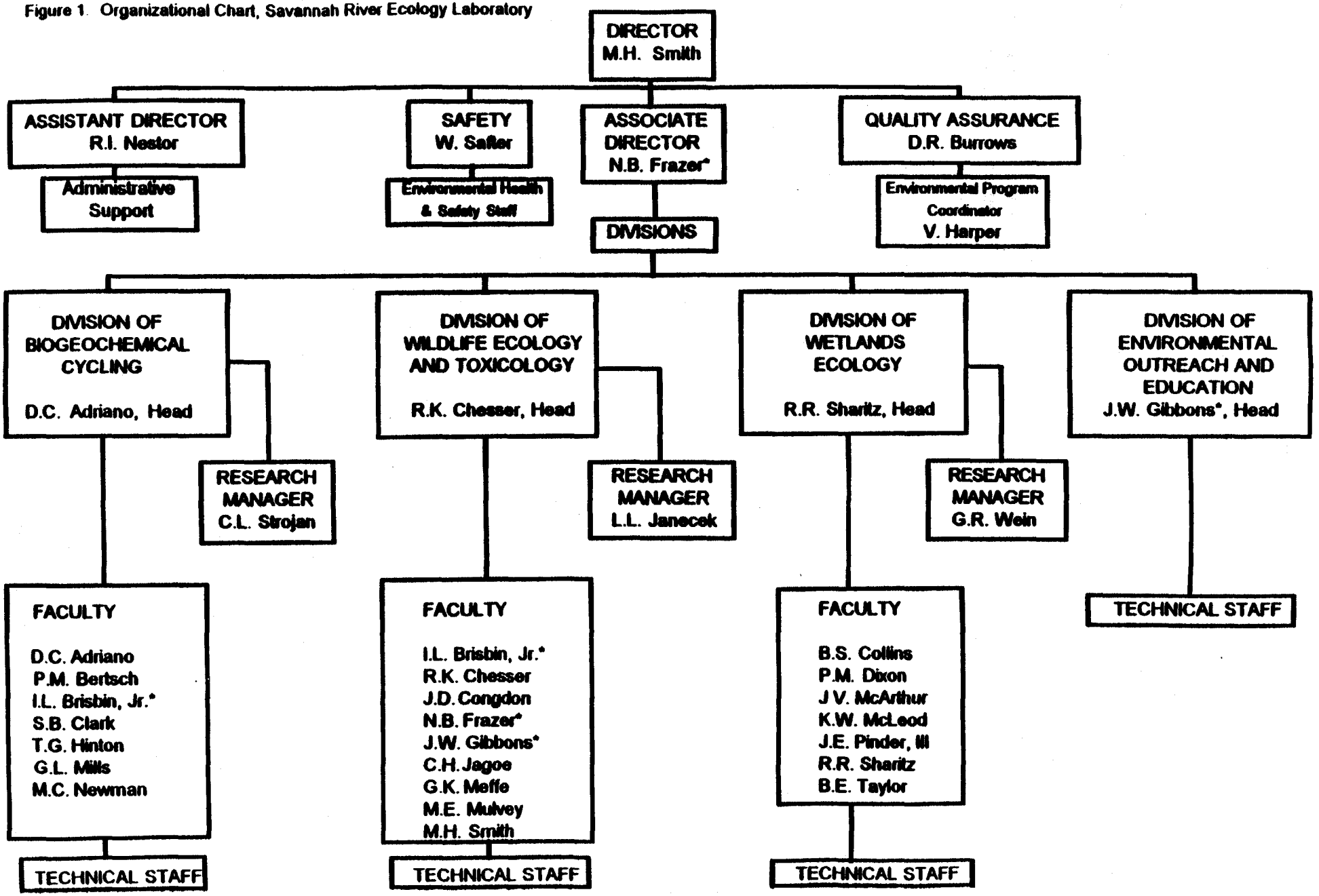
Joel Snodgrass. 1996. Influence of Beaver Ponds on Temporal and Spatial Dynamics of Southeastern Stream Fish Assemblages. Doctor of Philosophy, University of Georgia.

Pam Schultz. 1996. Characterization of Lipids in Water-Soluble Soil Colloids. Master of Science. Clemson University.

APPENDIX.

Figure 1. Organizational Chart, Savannah River Ecology Laboratory

Figure 1. Organizational Chart, Savannah River Ecology Laboratory



(7/7/95)

*Denotes joint affiliation