ELEVENTH ANNUAL

# SCIENTIFIC RESEARCH MEETING

MAY 23-24, 1985



NATIONAL PARK SERVICE

UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS NATIONAL PARK

# ELEVENTH ANNUAL SCIENTIFIC RESEARCH MEETING

The Uplands Areas of the Southeast Region
National Park Service

May 23-24, 1985

Great Smoky Mountains National Park
Gatlinburg, Tennessee

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# A REVIEW OF UPLANDS FIELD RESEARCH LABORATORY ACTIVITIES FOR THE PAST YEAR

*John D. Peine*
*Director, Uplands Field Research Laboratory*
*Great Smoky Mountains National Park*
*National Park Service*

As was predicted in this same forum a year ago, the year since the Tenth Annual Scientific Research Meeting in the Great Smoky Mountains National Park has been a period of absorbing the previous year's growth and project initiation. The production of new research reports from the Uplands Field Research Laboratory has been quite extensive. The major activities of the Uplands Lab during the past year are summarized as follows:

## Man and the Biosphere Program

The Uplands Lab staff was responsible for organizing and hosting the Conference on the Management of Biosphere Reserves last November. Jointly sponsored by UNESCO, the national MAB committees of the U.S. and Canada, and various U.S. agencies and organizations, the conference was attended by more than 180 administrators, scientists, resource managers, educators, and other specialists. Mr. Bill Gregg, Co-Chairman of the U.S. MAB Project Directorate on Biosphere Reserves, recently reported on the conference in Orion (vol. 4, no. 3, Summer 1985):

> "The participants came forward with scores of recommendations for actions that could be taken by administrators of protected areas to put biosphere reserve status to work for better resource information, better cooperation, and better management. But perhaps the most important result of the conference was the enthusiasm it generated; what many administrators had heretofore regarded as a gratuitous honor was now recognized as an international call to demonstrate the value of conservation in sustaining society."

This function took an inordinate amount of Lab resources but was very rewarding. One of the positive developments during the conference was the establishment of a joint research program between Uplands Laboratory and the MAB committees from China and Mexico, which seeks to produce a standardized format for reserve species listings.

Air Quality

The operation of the Look Rock air quality monitoring station continues jointly between the Uplands Lab and the State of Tennessee. Some equipment upgrading has been accomplished. Data editing has been somewhat automated and has been completed for calendar year 1984. The visibility data has taken on added importance, since the State of Tennessee has initiated action to develop a visibility component of the State Implementation Plan of the Federal Clean Air Act.

A new ozone monitor has just been installed at the Cove Mountain fire tower. Initiation has been delayed on the Oak Ridge National Laboratory's study of the effects of atmospheric deposition on canopy and soil processes and on elemental accumulation, cycling, and losses in forest ecosystems.

Spruce-Fir

The Spruce-Fir Ecosystem Assessment Program, coordinated by the Southern Appalachian Research/Resources Management Cooperative (SARRMC), began to take shape. Peter White is the co-principal investigator for the study's first objective: to assess the extent and severity of forest growth decline. Christopher Eagar coordinated a project to establish over 20 permanent vegetation plots in the red spruce ecosystem of the park, which will be used by the SARRMC research team. Congressional testimony in Washington, D.C. concerning air pollution problems in national parks brought added media attention to the spruce-fir ecosystem issue and to the air quality research program at Uplands, which is described in a paper presented at the National Acid Precipitation Assessment Program Review in November, 1984, at Asheville, North Carolina (Eagar et al.).

Botany

The series of fuel- loading studies were completed by Niki Nicholas and Peter White. They included data on mortality due to the balsam woolly aphid and the southern pine beetle. These products are of key importance to the refinement of the park's fire management policy. The hog exclosure monitoring program continues into its second year. Charlotte Pyle completed the disturbance history project. Her report is being published.

Progress on the development of a new vegetation map based on remote sensing data was greatly enhanced by the support of the National Aeronautics and Space Administration (NASA). A program of cooperative effort with NASA is just under way and represents the most important new collaborative effort initiated this past year.

Wildlife

Greg Wathen concluded the data collection for his study of deer ecology and hemorrhagic disease in Cades Cove. An involved data analysis is now under way. The Proceedings of the Workshop on Hog Control, prepared by Jane Tate, was published, along with an updated analysis of the park's hog capture data. The study to establish a parkwide monitoring plan for hog rooting is being finalized by Chris Eagar.

The "most ambitious study of the year award" goes to the hog bait preference project. This project, under the direction of Dr. Jim Jensen of the University of Tennessee School of Veterinary Science, and Greg Wathen, is to test bait preferences of wild hogs, both of scent and food. An elaborate set of pens were constructed to test the animals in a relatively undisturbed setting. Rick Noseworthy has shouldered the load of day to day activities most admirably. The task has proven to be very labor intensive, and many volunteers have added immensely to the effort.

Sociology

A report was completed on an evaluation of communications with visitors to the Great Smoky Mountains National Park. Several of the recommendations of the study have already been implemented. Proceedings were also published from a workshop on unobtrusive techniques to study social behavior in parks. Primary data collection last

summer focused on visitor behavior in the vicinity of various hazardous areas. Insight gained will be used to provide the most effective techniques to communicate these dangers to the most high risk clientele. Experimentation with the touch screen computer in the visitor center continued again last summer. A trip planning program proved very popular. No sociology paper abstracts are presented at this forum since social research in the park was reported at a separate gathering of social scientists at Uplands Laboratory on March 15 and 16.

Fisheries

In mid-year, Mark Alston left to take a job in a nearby school system. We wish him well and miss his expertise. Appointment of a replacement scientist in aquatic ecology has been delayed. The sport fisheries monitoring report was completed. The brook trout habitat study remains in limbo.

Overall, the Laboratory had a very productive year, completing many projects. The other major progress was in securing cooperative research projects with Oak Ridge National Laboratory, NASA, and SARRMC. These projects expand our scope and direct ties with leading scientists and their institutions.

# ECOLOGICAL AND GENETIC PROPERTIES OF FAUNAL REPRESENTATIVES FROM DISTURBED WATERSHEDS[1]

Alan E. Stiven, Curriculum in Ecology, University of North Carolina, Chapel Hill, NC 27514

Richard C. Bruce, Department of Biology, Western Carolina University, Cullowhee, NC 28723 and Highlands Biological Station, Highlands, NC 28741

Both ecological and isozyme genetic properties of populations of the stream salamander, *Desmognathus quadramaculatus*, and land snails of the genus *Mesomphix* were investigated in watersheds at the Coweeta Hydrological Laboratory and the Great Smoky Mountains National Park (GSMNP). The study focused on the consequences of forest cutting on the ecological genetics of selected species that would have been subjected to population declines, bottleneck effects, and hypothesized changes in genetic diversity. Three sets of disturbed (cut forests) and control sites were used in the investigation, two at Coweeta and one in GSMNP.

Variation in densities and size structure were obtained from periodic sampling. Mortality and growth rates were derived from enclosure experiments. Individuals of all species were sacrificed for electrophoretic analyses of several loci. Analyses of genetic structure and diversity were assessed within and among watersheds, and between Coweeta and GSMNP.

In *D. quadramaculatus*, mean adult body size was significantly larger at the Coweeta sites than at the GSMNP sites. Larger size was also characteristic of the control watershed at the high elevation site at Coweeta. Based upon data from 14 loci, genetic variability (fraction of loci that are polymorphic and mean heterozygosity) was higher in the GSMNP watersheds than at Coweeta. However, prior disturbed watersheds at Coweeta and GSMNP exhibited higher values of mean heterozygosity than their control counterparts.

The endemic land snail, *Mesomphix andrewsii*, was more common in lower elevation watersheds. *Mesomphix subplanus* dominated higher sites. In general, snails appeared more abundant in prior disturbed watersheds, and Coweeta sites were on the average more populated than GSMNP sites. Growth rates of marked *M. andrewsii*

were generally lower in prior disturbed and in lower elevation watersheds at Coweeta. Mortality, while varying seasonally, was largely independent of forest elevation or watershed treatment. Electrophoretic analyses showed that the lowest levels of genetic variability occurred in the GSMNP for both species. Heterozygote deficiency for most loci was also common at many sites, especially for *M. subplanus*.

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[1]This research was supported by the USDA Forest Service, in collaboration with the U.S. Man and the Biosphere Program.

## COMPARISON OF MICROHABITAT SELECTION AND DIET OF BROOK TROUT *(SALVELINUS FONTINALIS)* AND RAINBOW TROUT *(SALMO GAIRDNERI)* IN A GREAT SMOKY MOUNTAINS NATIONAL PARK STREAM

- - S. C. Lohr and J. L. West, Department of Biology, Western Carolina University, Cullowhee, NC 28723

Substantial evidence suggests that the continued decrease of native brook trout range in the Great Smoky Mountains may be attributed to competition with introduced rainbow trout. To determine whether competition exists for suitable microhabitats and food, underwater observations were made characterizing the positions of sympatric individuals in a section of Palmer Creek. Rainbow trout were removed with electroshockers and observations were repeated on the remaining brook trout. Benthic macroinvertebrate, drift, and stomach content samples were collected both before and after rainbow trout removal.

Interspecific differences for selected focal point characteristics were observed between the species. Brook trout occupied focal points more associated with overhead cover and at greater depths below the water surface than did the rainbow trout. Rainbow trout removal had the greatest effects on the focal points occupied by age 0 brook trout. They exhibited significant movements into deeper water and away from cover. Older brook trout responded to rainbow trout removal by also shifting to positions farther from cover but to a lesser degree than the age 0 fish. Age 0 brook trout appeared to select stream positions vacated by older rainbow trout. No

significant differences for focal point water velocity and velocity difference existed between age 0 and older fish of both species.

Both species fed on most invertebrate taxa below their occurrence in the drift. The greatest diet differentiation occurred between older fish, with brook trout selecting salamanders more frequently than rainbow trout. Diptera and Trichoptera were selected more frequently by post- removal fish of both species. This may have been caused by the greater seasonal abundance of these taxa in the stream. It appears that both species of trout use the food resources in proportion to their abundance. Thus, food was not a limiting resource at the time of the study.

## A COMPARISON OF LIFE HISTORIES OF BROOK TROUT IN ALLOPATRIC AND SYMPATRIC POPULATIONS IN A WESTERN NORTH CAROLINA STREAM

-- R. Scott Urwick and Jerry L. West, Western Carolina University, Cullowhee, NC 28723

The life history of the brook trout *(Salvelinus fontinalis)* in the U.S. has been studied in considerable detail in the northeast and midwest, but not in the southern Appalachians. In addition, there has been concern in recent years of the potential impact of the exotic rainbow trout *(Salmo gairdneri)* on the native brook trout.

The purpose of this research was to study certain aspects of the life history of the brook trout in the southern Appalachians and to compare an allopatric population and a population that is sympatric with rainbow trout. The study was done on two 100-meter sections of Rough Butt Creek in Jackson County, North Carolina. The two sections were very similar, approximately 100 meters apart and were separated by a barrier to fish movement.

The two populations were similar in size. In the sympatric section the rainbow trout had a significantly greater condition factor than the brook trout, but it was similar in the two brook trout populations. Principal component analysis of diet indicated that Ephemeroptera, Plecoptera, Trichoptera and vegetation were consumed in summer more than in other seasons, with rainbow trout eating more of these items

than either of the brook trout populations. The older fish (3+) in all populations ate more larger prey items (crayfish and caterpillars) than did the younger ones. Terrestrial insects, salamanders and diptera larvae also were eaten more in the summer than in other seasons.

The study is not complete. Growth and fecundity data are still being analyzed.

## ALTITUDINAL MIGRATION AND CHOICE OF WINTERING GROUND BY CAROLINA JUNCOS IN THE GREAT SMOKY MOUNTAINS

– – Kerry N. Rabenold and Patricia P. Rabenold, Department of Biological Sciences, Purdue University, West Lafayette, IN 47907

The unique avifauna of the southern Appalachian spruce- fir ecosystem is dominated by populations that migrate altitudinally from the high elevation breeding ground to low elevation valleys in winter. These altitudinal migrants probably determine the differences in avian species composition that distinguish these forests from northern boreal forests. We are studying the most abundant altitudinal migrant, the Carolina Junco, *(Junco hyemalis carolinensis)*, to test hypotheses concerning ecological determinants of winter distribution and distance travelled in migration. Over five years in the Great Smoky Mountains, we have individually marked more than 2,000 juncos, including Northern Juncos *(J. h. hyemalis)* that are latitudinal migrants present in winter.

Carolina Juncos spend the winter at higher elevations than Northern Juncos. Above 600 m elevation in the drainage that forms the study area, juncos are 76% Carolinas in winter on average. Carolina Juncos show winter assortment by sex across altitudes that parallel the latitudinal assortment found among Northern Juncos in other studies. Most Carolinas wintering above 600 m elevation and within 20 km of ridgetop breeding habitats are males (77%). Farther downslope, most juncos are Northerns (83%) and most Carolinas are females (80%). Some male Carolinas are year-round residents in the spruce-fir breeding habitat, while others migrate through the entire altitudinal range. Differential altitudinal migration by the sexes of Carolina Juncos and altitudinal segregation of the two subspecies in winter are variable between years; smaller and

competitively subordinate classes of juncos are better represented at higher elevations in milder winters. This variation, and patterns of survival and ranging revealed by recapture data, are consistent with the hypothesis that social dominance in competition for food significantly affects winter distribution.

Continuing studies are focusing on the phenomenon of social dominance and its effects on the physiology and ranging patterns of individuals. Carolina Juncos are clearly dominant over Northern Juncos in aviary tests, and the physiological effects of this dominance are noticeable. Extensive recapture information for a winter population in one low elevation area suggests that subordinate females range more widely and are less able to put on fat in harsh weather than the dominant males. These effects on socially subordinate individuals could be the proximate cause of differential and partial migration among Carolina Juncos and patterns of winter distribution.

## BLACK BEAR SPACING PATTERNS, PHILOPATRY AND HABITAT PRODUCTIVITY

– – Roger A. Powell, Department of Zoology, North Carolina State University, Raleigh, NC 27659-7617

The few long-term studies of black bears *(Ursus americanus)* show that the spacing patterns of this species are variable over its range. However, philopatry for natal home ranges by females has been found consistently. Applying a theoretical framework to studies of this species and incorporating known patterns for dispersal can help us to explain and to predict the variations in spacing patterns. For food-limited species, models predict that territorial behavior should be exhibited only in areas with intermediate habitat productivity. Where habitat productivity is near the upper limit for territorial behavior, models predict that the spacing pattern exhibited could be one of at least two options, depending on food patchiness: complete territoriality with territory site smaller than at lower habitat productivity, or partial territoriality. In boreal forests of North America, years with poor bear food supplies lead to reproductive failure in black bears, indicating that this species is food-limited. Female black bears in these forests exhibit territorial behavior and mothers appear to relinquish parts of their territories to their female offspring. In the southern Appalachian Mountains, black bear food is patchily distributed and habitat productivity is

considerably higher than in northern forests. Models predict partial territoriality or no territoriality at all for female black bears in this region and in fact they do exhibit considerable home range overlap as measured by the sums of the probabilities that two females will be in the same place at the same time. These probabilities have been calculated using a method of plotting home ranges that uses animal location data to generate the probability distributions. This method has many advantages over conventional methods of plotting home ranges.

## TVA GEOGRAPHIC INFORMATION SERVICES

- - Bruce Rowland, Office of Natural Resources, Tennessee Valley Authority, Norris, TN 37828

To achieve sustained economic growth consistent with resource capabilities and environmental values, resource managers in the Tennessee Valley must have ready access to accurate information about the region and its resources. Many "layers" of data must be combined and interpreted to deal with today's complex issues. An up-to-date profile of the environment is essential for sound decisions about the balanced use of our region's resource base.

The Geographic Information Services staff seeks to provide resource managers in the Tennessee Valley the best available spatial analysis tools to inventory and interpret information about the region's resources and their potential for development. A key element is the operation of a computer-based Geographic Information System (GIS). The system is used to solve the problem of integrating the many types of available data concerning natural resources, physical land characteristics, land uses, economics, and environmental conditions. Using GIS, planners may compile from many sources (maps, field notes, remote sensing, statistical data, etc.) a consistent, interpretable base of information relevant to specific development decisions.

Geographic Information Services provides technical support for multiple use planning and management on agency lands bordering the TVA reservoir system. In addition, GIS serves a variety of other TVA activities throughout the region, including industrial siting, planning electric power facilities, and monitoring regional economic and environmental trends.

Geographic Information Services also seeks to be a catalyst encouraging the use of modern resource analysis technology by others outside TVA. GIS services and data bases are made available on a reimbursable basis to other Federal and State agencies, county governments, and communities faced with resource development decisions. Planners and resource managers receive a valuable opportunity to apply the state-of-the-art GIS technology maintained by TVA to local activities and evaluate their individual requirements before making large investments in computer-based systems of their own.

For additional information contact:

Geographic Information Services
TVA Office of Natural Resources
Norris, TN 37828
(615) 494-9800

## THE KNOX COUNTY GEOGRAPHIC INFORMATION SYSTEMS PROGRAM

- - John Lutz, Metropolitan Planning Commission, Knoxville, TN 37902

The almost universal need of city and county governments and utility companies for up-to-date maps has served as a motivating force for the development of the Knox County geographic information system (GIS). The Knox County GIS will be integrated in the sense that it will serve the geographic information needs of city and county departments as well as those of the electric, water and gas utilities. The integrated aspect will reduce the efforts required to keep the numerous map sets updated by requiring only the cognizant agency to make changes. The aerial photography which will be used to make the base map for the GIS was completed in March 1985 and conversion to a digital planimetric base map will commence in the fall of 1985. Uses anticipated for the system include: production of thematic maps to aid in the planning process, daily updating of planimetric and cadastral maps, dispatching of utility repair crews, emergency service dispatching, and many other uses, some of which have probably not been thought of yet.

# THE TENNESSEE STATE GIS PROGRAM

-- Clifton J. Whitehead, Tennessee Wildlife Resources Agency, P.O. Box 40747, Ellington Agricultural Center, Nashville, TN 37204

For several years, the State of Tennessee has been working to identify the specific needs for and requirements of an automated system to support the management and analysis of geography-based information. Based upon the findings of several studies, a decision was made to develop a state information system with extensive capabilities for the management, analysis and display of geographically-based data.

As an agency historically responsible for handling large data sets shared by multiple users, the Tennessee Wildlife Resources Agency (TWRA) was designated as the ongoing manager and development agency for a statewide geographic information system, and given responsibility for the continual building of data resources on land use, soils, socioeconomics, agriculture, forestry, and other data needed for the comprehensive system.

TWRA has been directed to provide system analysis services and data base management responsibilities for many state agencies, including the Departments of Agriculture, Conservation, the Wildlife Resources Agency, the University of Tennessee Institute of Agriculture, the Middle Tennessee State University, and other organizations. These agencies, as well as the Governor's Office, have indicated support for a TWRA role in managing data on geographic activities in conjunction with its currently designated responsibilities. By centralizing the multi-agency GIS system with TWRA, a focal point was created for establishing and enhancing better management of all natural resources within the State.

System capabilities are now being developed to support the data storage, analysis, manipulation and display needs of the foregoing agencies. The software procedures and techniques under development are similar to those used in the surface mining programs in the States of Kentucky, Illinois and Alaska, as well as in a vast array of other types of programs nationwide.

# APPLICATIONS FOR THE SMALL COMPUTER INFORMATION PROCESSING SYSTEM (SCIPS)

- - Ronald J. Cornelius, Minerals Management Specialist, Big South Fork National River and Recreation Area, P.O. Drawer 630, Oneida, TN 37841

The Big South Fork National River and Recreation Area (BISO) is a relatively new area within the heart of the Tennessee and Kentucky coal fields and Tennessee's oil and gas field. Since mineral extraction activity is permitted within the boundaries of the national area, management is frequently called upon to evaluate proposals made by private mineral development companies, as well as to review assessments by other agencies which deal with activities that may affect the Big South Fork watershed.

At the present time, decisions must be made by using data which is stored in a multitude of reports, charts, status reports, and maps of various scales and reliability. The need for retrieval and analysis of this accumulation of data on a timely basis led to the creation of SCIPS to assist management in making sound decisions where mitigation of impacts to endangered and threatened species, water quality, cultural resources, and recreational uses is a concern. Sixteen themes or data base files have been identified as potentially useful for resource management activities. SCIPS not only allows analysis of data and generation of a map product, but data, other than geographic-type data which is entered during the digitizing sessions, can be recalled as hard copy. Although designed with mineral development in mind, other park functions have seen uses for an in-house GIS; i.e., sign inventories, roads and trails inventories, search and rescue functions, law enforcement, and deer hazard areas, to name a few.

## DIGITAL ELEVATION MODELS AND SOIL SURVEY MAPS

- - F. Paul Baxter, Tennessee Valley Authority, Norris, TN 37828

Digital elevation data now becoming available through the topographic mapping process will become a valuable tool in spatial analysis using geographic information systems to create new information such as slope, aspect, shape, landscape position, and drainage network. This new information will be very useful as a new way for soil scientists to produce soil maps in regions of limited access and rough terrain.

Procedures for making derived soil maps using digital terrain and other data are described and three levels of analysis are discussed. New geographic information system applications are identified in controlling energy, fertilizer and pesticide inputs used in intensive agricultural land management. Opportunities in utilizing geographic information systems in ecological research and forest management are also presented.

## REMOTE SENSING AND VEGETATION MAPPING IN GREAT SMOKY MOUNTAINS NATIONAL PARK, NORTH CAROLINA AND TENNESSEE

- – Peter S. White and Mark D. MacKenzie, Uplands Field Research Laboratory, Great Smoky Mountains National Park, Gatlinburg, TN 37738

Remote sensing is a valuable tool for resource tracking. A vegetation mapping project using aircraft-collected, multi-spectral scanner (MSS) data has been carried out at Great Smoky Mountains National Park since 1982. The data set consists of March and June, 1982, overflights of the park, with a mean resolution (pixel size) of 13 m x 13 m. These data have been processed with the NASA software package ELAS. To date, we have shown that the major evergreen vegetation types in the park (spruce-fir, hemlock, pine, heath balds) can be successfully mapped with this technology. In the forest type that we have focused on (spruce-fir) we have been able to successfully interpret seven subtypes. In 1985 we are working with NASA, USFS, Oak Ridge National Laboratory, and the University of Tennessee to complete and extend this work. In Great Smoky Mountains National Park, remote sensing will allow us to map the extent and monitor the condition of critical resources (e.g., high elevation

spruce- fir forests impacted by an exotic insect and air pollution). The technology also holds the promise of the detection of finer scale problems (e.g., the detection of pre- visual stress in forest trees exposed to pollutants). The mapping and analysis of resources may represent a common focus for diverse groups within the southern Appalachian region.

## SELECTION AND IMPLEMENTATION OF A GEOGRAPHIC INFORMATION SYSTEM FOR THE GREAT SMOKY MOUNTAINS NATIONAL PARK

- - James R. Carter, Geography Department, University of Tennessee, Knoxville, TN 37996- 1040

The author is working with the staff of the Uplands Laboratory to select and implement a geographic information system for use within the park. The resources identified at the beginning of the project included the following: an IBM PC and dot matrix printer at the Uplands Lab; a 1200 Baud modem and line to the University of Tennessee, Knoxville, computers; 7–1/2 minute digital elevation models for about a third of the park; a digitized vector data base created by the Denver Service Center for all streams, trails, and point features within the park; and a digital vegetation data base being prepared by the Denver Service Center. After considering a variety of possibilities, a polygon- based GIS software package was purchased from Iris International for installation on the IBM PC at the Uplands Lab. The package has no image processing capabilities, but it can utilize the vector data bases. This package required updating the PC for greater graphics resolution and the purchase of a digitizer for interaction with the software. Various factors caused delays in getting all of the components together until two weeks ago.

A tape of the vector data base was read on the mainframe computers at the University of Tennessee. The vector data for the Cades Cove quadrangle was modified slightly and downloaded onto a floppy diskette for use in the GIS. The preliminary results look promising. The 1:250,000 digital elevation model for the area covering the park was purchased and the author is using it for the study of slope, elevation, and aspect for the entire park. The U.S. Geological Survey has informed us that digital elevation models for the rest of the park are scheduled for production in the near future

and we are to get those when they become available. The Denver Service Center has had trouble rectifying the scanner data to produce the digital vegetation map, but with the assistance of the NASA Earth Resources Laboratory, the data is now in more acceptable form and we anticipate tapes of the vegetation data in the near future.

The IBM PC-based GIS is a limited system that should give us the ability to address some local problems and to gain a better understanding of how a GIS can address questions in the park. To incorporate the voluminous digital elevation models and the vegetation data base over extensive areas will require the use of a more powerful system. Various possibilities are being considered, including the implementation of the Interior Department packages MOSS or SAGIS on one of the computers at the University of Tennessee, Knoxville, or using a similar software package on a remote facility from which we would buy time.

## SPECIES-AREA RELATIONSHIP OF RARE AND ENDANGERED VASCULAR PLANTS IN GREAT SMOKY MOUNTAINS NATIONAL PARK

-- Ron Miller, Institute of Ecology, University of Georgia, Athens, GA 30602

Research results from Great Smoky Mountains National Park are presented to illustrate an approach for quantifying species-area effects and the influence of natural features distribution on the distribution of rare and endangered natural plant species. The accumulation of newly recorded rare and endangered species has achieved an asymptote in the Smokies region. The adjusted coefficient of determination ($r^2$) is used to determine the degree to which the species-area relation influences the abundance of rare and endangered plant species within the Smokies region. It is suggested that the vulnerability of individual species to extirpation can be assessed from considerations of their natural history characteristics and the size of the regional species pool. Rather than concentrating on the protection of as yet undocumented dynamic processes, the long-term preservation of rare plants should be directed towards protecting the integrity of vulnerable species, habitat components, and characteristic gradient patterns within Great Smoky Mountains National Park.

# FLORISTIC STUDIES OF FORT DONELSON NATIONAL MILITARY PARK, STEWART COUNTY, TENNESSEE

- - Edward W. Chester, Austin Peay State University, Clarksville, Tennessee 37040

Fort Donelson National Military Park, a 240-ha historic site in northwestern middle Tennessee, preserves the battlefield of a major Civil War engagement and includes a national cemetery. Located within the dissected western Highland Rim Section of the Interior Low Plateaus Physiographic Province, the park is mostly upland but adjoins the Cumberland River (Lake Barkley) and is thus topographically diverse, with conditions ranging from xeric ridges to bottomlands. The underlying bedrock of cherty limestone outcrops in some ravines, and a few bluffs occur along the river. Elevations range from 110 to 168 m above sea level.

The park is within the Western Mesophytic Forest region of the Deciduous Forest Formation, a transitional zone between and including elements of the more xeric Oak-Hickory region to the west and the more mesic Mixed Mesophytic region to the east. As such, presettlement vegetation consisted of a mosaic of unlike, mostly mixed hardwood communities. Phases of oak and oak-hickory forest prevailed on the rolling uplands of the western Highland Rim.

The vegetation of the park has been disturbed since settlement. While some old growth forests occur, such cultural sites and communities as lawns, meadows, picnic grounds, scenic areas, old homesteads, and fencerows predominate. Small wetland areas resulting from fluctuating Lake Barkley water levels, successional fields, outcrops, and various slope aspects increase the habitat types and thus the floristic diversity.

This study proposed to (1) develop an annotated checklist of the vascular plants, (2) compile a list of introduced taxa, noting their apparent influence upon native vegetation, and (3) determine if any rare species occurred. Results reported are based upon 35 collecting trips made during the 1982-1984 growing seasons; studies continue in 1985.

The presently known flora consists of 630 species representing 350 genera and 102 families. The pteridophyte flora is relatively small (14 species) and with the exception of *Lycopodium flabelliforme* and *Ophioglossum vulgatum,* consists of expected

taxa. *Juniperus virginiana* is the only gymnosperm outside of cultivation. Of the 608 angiosperms, species of Asteraceae and Poaceae dominate and account for more than 25 percent of the flora.

About 22 percent of the flora is exotic or not indigenous to the park. Most of these 137 species are naturalized or planted and appear to have little influence upon native vegetation. Troublesome exotics include *Albizzia julibrissin, Ligustrum sinense, Lonicera japonica,* and *Rosa multiflora.* No rare species of national significance were found, but four taxa, *Lesquerella lescurii, Lilium michiganense, Ludwigia leptocarpa,* and *Panax quinquefolium* are of concern in Tennessee.

## INTERPRETATION OF GEOBOTANICAL EVIDENCE TO DEDUCE CHANNEL MORPHOLOGY CHANGES IN AN EAST TENNESSEE COAL AREA STREAM

-- Bradley A. Bryan and Cliff R. Hupp, U.S. Geological Survey

Stability of channel segments and conversely rates of bank widening, aggradation, or scour can be determined accurately using a variety of geobotanical techniques involving tree growth forms and patterns of tree rings. On-site events such as flooding, deposition, bank caving, and the removal of competitor trees result in scarred boles, eccentric and suppression-release growth ring patterns, buried stems and development of adventitious root zones, and conversion of stem-wood to root-wood or root-wood to stem-wood.

Geobotanical evidence collected at several sites along Smoky Creek, a heavily surface-mined basin, was used to determine temporal and spatial changes in channel and bar morphology that have occurred over at least the last 11 years. Smoky Creek is a tributary of the New River, which combines with Clear Fork to make up the South Fork of the Cumberland River in northeastern Tennessee. Surface-mining has resulted in much coarse debris being moved through stream channels primarily as bedload. This increased bedload has caused rapid changes in channel morphology through the formation of in-channel bars which induce channel migration.

One bar has been in place since at least 1973. Trees that were buried, damaged, or showed altered growth characteristics indicated about 0.6 meters of vertical

accretion from 1980 through 1983 over the bar area of 1,600 square meters. Vegetation samples from a second bar, 2.4 kilometers upstream and in place since at least 1979, indicate about 0.5 meters of vertical accretion from 1982 through 1983 over an area of 930 square meters. Channel migration is evidenced at both sites by stabilization of the landward bar surface and erosion of the opposite bank of the stream.

## MORTALITY PATTERNS AND SUCCESSIONAL TRENDS IN A VIRGIN FOREST

- – Charles E. McGee, Principal Silviculturist, USDA Forest Service, Southeastern Forest Experiment Station, Sewanee Silviculture Laboratory, The University of the South, Sewanee, TN

Dick Cove is a 100-acre virgin stand of mixed mesophytic hardwoods on the Cumberland Plateau of Tennessee. The stand contains numerous large oaks and hickories, with occasional yellow-poplar, elm, and a few other species. Northern red oak has been the predominant species in the overstory; however, recent high mortality among the large oaks and hickories may change the character of the stand. Approximately 615 dominant or codominant trees died between 1979 and 1984. The dead dominant and codominant trees ranged in age from 90 to 375 years, and included 193 northern red oak, 95 other oaks, 244 hickories, 20 elms, 5 yellow-poplar, 7 sugar maple, and 8 white oaks.

Examination of the residual living stand suggests that significant changes in species composition can be anticipated. Although 15 of the 25 stems per acre in the living stand larger than 17 inches dbh are oaks and hickories, definite deficiencies appear in the smaller size categories. On the other hand, the number of sugar maple, white ash, and yellow-poplar appear to be increasing. There are large numbers of sugar maple of all size classes well distributed across the entire study area. White ash has large numbers of trees in certain size categories and is relatively well distributed. Yellow-poplar has a large number of stems in some areas but is not well distributed.

Thus, a stand in which oak-hickory has been predominant for many years may be phasing into a stand where hickory and oak would still be important components, but where sugar maple would become the predominant species, with northern red oak as only an occasional member of the community. The extensive mortality that occurred in

a brief 5- year period has definitely changed the appearance and value of this old forest. A major concern is whether or not concentrated periods of high mortality can be expected in other protected hardwood stands as they age.

## A PHOTOGRAMMETRIC ANALYSIS OF CHANGES IN FOREST PATCH DISTRIBUTION ALONG THE GREAT SMOKY MOUNTAINS NATIONAL PARK BORDER

- - Jonathan Ambrose, Institute of Ecology, University of Georgia, Athens, GA 30602

Changes in land use outside national parks can greatly influence the spatial distribution of natural community types near the legal boundaries, thus affecting the relative isolation of interior communities from those in adjacent non- park areas. In order to evaluate temporal changes in vegetation patterns in the vicinity of the Great Smoky Mountains National Park (GRSM) border, a photogrammetric survey was undertaken. Forested and cleared patches were mapped from 1953 and 1978- 82 aerial photographs of the park periphery onto USGS topographic quadrangles, and the amount of forested and unforested land was measured within each of six kilometer- wide zones from 3 km within the park to 3 km outside the park. Eight sections of the GRSM boundary, representing a variety of land uses adjoining the park, were examined.

Results of this survey indicate that areas within the park borders have experienced a slight increase in total forest cover and maximum forest patch width and a decrease in the number and size of cleared patches since 1953. For areas outside the park borders, the general directions of change were toward an increase in the number of forest patches and cleared patches, an increase in maximum cleared patch width, and a decrease in total forest cover and maximum forest patch width.

The Gatlinburg and Jones Cove sections of the GRSM border showed the most dramatic changes in number of cleared patches, number of forest patches, and maximum forest patch width from 1953 to 1978. The trends in vegetational continuity in these two areas were in opposite directions, however. In the Gatlinburg area, the recent expansion of development for tourism, recreation, and residential use has resulted in the fragmentation of large forest areas and the creation of a substantial amount of new forest edge. This forest fragmentation has been most pronounced in areas within 1 km of the park border, and represents a potentially serious threat to

populations of forest interior species in this zone. In the Jones Cove area, abandonment of small agricultural plots and a decline in small-scale logging operations have allowed the consolidation of forest patches through secondary succession.. However, future development for recreation and tourism in this area may cause a reversal of this consolidation process.

The comparison of changes in vegetational continuity for these eight sections of GRSM border has shown that simplistic models based on uniform spatial patterns of disturbance cannot adequately predict the relative isolation of the park's forest communities from those outside its borders. Instead, differences in the nature of disturbance effects along the park's borders should be investigated in order to develop a management scheme which is adaptable to local conditions in peripheral areas of the park. Information from aerial photographs and historic maps can be quite useful in this effort, both in the detection of temporal trends in vegetation patterns, and in the location of specific areas in which these trends indicate a need for concern.

## A FOREST FUELS INVENTORY OF GREAT SMOKY MOUNTAINS NATIONAL PARK

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A fuels inventory was carried out for the Great Smoky Mountains National Park (GRSM). Forest fuel levels (live and dead stem basal area ($m^2$/ha), live and dead stem density (stems/ha), downed twig and bole volume ($m^3$/ha), depth (cm) of 01 and 02 layers) were quantified and compared (analysis of variance, Duncan comparison of means) for 37 possible combinations of 21 forest types, three elevation classes (900-2500 ft, 275-760 m; 2500-4500 ft, 760-1370 m; 4500-6500 ft, 1370-1980 m), and two disturbance history classes (primary vs. secondary growth). With the completion of a remote sensing-generated vegetation map, the information in this report will be used to create a fuels map for the park. This parkwide fuels inventory included data from four previously published studies and two unpublished projects, as well as data collected specifically for this inventory.

Primary growth mesic communities had 3.8 times more live basal area (51.0 $m^2$/ha) than disturbed coniferous forest types (fir blowdowns, aphid-infested fir,

beetle-infested pine, burned pine). Fir blowdowns had the highest live stem density (14931 stems/ha). Primary and secondary growth high elevation coniferous communities had an average of 16.8 $m^2$/ha standing dead basal area compared to an average of 3.2 $m^2$/ha for the remaining forest types. Primary growth mid-elevation hemlock and hemlock-hardwood stands had 50% more downed woody debris than disturbed, high elevation coniferous forests (fir blowdowns, aphid-infested fir). Organic litter and soil depth was highest in mid- and high elevation coniferous forest types.

## WATERSHED BY WATERSHED EVALUATION OF GREAT SMOKY MOUNTAINS VEGETATION DISTURBANCE HISTORY

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In Great Smoky Mountains National Park (GRSM), aside from chestnut blight, the major pre-park vegetation disturbances were those directly due to people's activities, namely fire, farming, and logging. Successional changes in disturbed forests have a bearing on park management in terms of wildlife habitat, fire risk, and the visitor's experience. For both management and scientific studies based on the presence or absence of disturbance, mapped information on the type and extent of vegetation disturbance is necessary.

A small-scale overview disturbance history map, based on collation of map and written records in the GRSM Archives, was prepared. A dot grid was used on this map to derive the percentages of each land use category within the 28 major GRSM watersheds. Maps were presented showing percentages of each disturbance category by watershed. The land use categories were as follows: corporate logging (on corporately-owned tracts with large-scale operations involving railroads, mechanized skidders, and bandsaw mills); early-style logging (i.e., locally-based operations generally involving no mechanized equipment); concentrated settlement; diffuse disturbance (including homesites and early style logging operations scattered through a large area or grazing by free-ranging livestock or intentionally set fires in the forest understory); areas of diffuse disturbance containing big tree stands; intense fire; and areas high in virgin forest attributes based on little or no record of pre-park disturbance.

The most extensive disturbance was corporate logging, which covered 40 percent of the park. In contrast, areas of concentrated settlement comprised only 9 percent of the park. Intense fire followed corporate logging in 23 percent of the area cut using a high degree of mechanization. Fire following highly mechanized logging accounted for 87 percent of the total intensely burned area in the park. Twenty- one percent of the park was affected by diffuse disturbance, while areas of diffuse disturbance with big tree stands accounted for another eight percent of the park. These diffusely disturbed areas are the crux of the difference between my estimate of 20 percent for areas high in virgin forest attributes, versus others' designating as much as 40 percent of the park as virgin.

## THE 1984 GREAT SMOKY MOUNTAINS SOIL SURVEY

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The Soil Conservation Service prepared a soil survey of designated research tracts between Newfound Gap and Clingman's Dome during the summer of 1984. This soil survey will be used as basic soil data in ongoing research at high mountain elevations.

The soils maps were made in three stages. The first stage was to make a broad separation on the geology of the area. The geology of the Newfound Gap area is dominated by the Anakeesta formation. These high sulfur, low pH–bearing rocks are thinly bedded and unstable. These areas are characterized by sharp–topped mountains. The Chimneys are a good example. Thunderhead sandstone is the other primary geological formation and is characterized by rounded, fairly wide, dome–shaped mountaintops. Clingman's Dome is an excellent example. These rock formations are more stable than Anakeesta and are coarser textured. The second stage was to delineate computer–generated aspects on a color infrared photo base at 1:33,000 scale. The third stage was to ground truth signatures on infrared photography and make refinements in computer–generated aspect variations. The fire–damaged area near Clingman's Dome was different taxonomically because it has a much thinner surface than would be predicted at this elevation. This, of course, was not shown on the computer–generated aspect maps.

The finished map had 10 delineated areas called mapping units. These areas represent areas that should be managed differently. Geographical areas were delineated on slope, aspect, degree of stoniness, parent rock, and influence of man. Each delineation is an attempt to show a unique combination of soil-site factors.

Map symbols 1 and 3 are Pachic Haplumbrepts. They are separated on geology. Map symbol 1 is formed over quartzite in the Thunderhead sandstone formation and the rock fragments on the surface are large and interfere with use of the area. Map symbol 3 is in an Anakeesta formation and the rock fragments are small but the area is unstable and prone to landslides.

Map symbols 2, 4, and 9 are all Typic Haplumbrepts. They are separated on geology and aspect. Map symbol 2 is in a quartzite area of the Thunderhead sandstone formation, and the rock fragments are large enough to interfere with use. Map unit 4 is in a concave landscape and protected from the wind and is a very productive red spruce site. Map symbol 9 is in the Anakeesta formation and rock fragments are too small to interfere with soil use. These soils are unstable and prone to landslides.

Map symbols 5 and 6 are Lithic Haplorthods. Map unit 5 is generally covered with large stones that interfere with soil use and map symbol 6 is not covered with large stones.

Map symbols 7, 8, and 10 are all Umbric Dystrocrepts. Map unit 7 is in the Anakeesta formation and rock fragments are too small to interfere with soil use. The soils are prone to landslides. Map symbol 8 is in a quartzite area of the Thunderhead sandstone formation, and soils are more stable and less prone to landslides. Map unit 10 is in a quartzite area of the Thunderhead sandstone formation. These soils have been burned and support only scattered tree vegetation.

This soil survey report did not classify soils found to the series level in the current soil classification system. No established soil series were available at the time of field work and the area studied was too small to adequately characterize a new soil series. Studying these soils and proposing soil series will be the natural progression of soil survey activities in the Great Smoky Mountains National Park.

Summary

This soil survey made the following observations: (1) Geology has a very important role in soil formation in the Newfound Gap - Clingman's Dome area. Geology dictates width of the ridges, sideslope stability, and size of the surface stones. (2) Ridges are the only parts of the landscape that are residual in the soil formation process. Most non- ridge landscapes exhibit some soil creep. Ridgetops are susceptible to high winds and tree throw is a problem. (3) Colluvial areas (map unit 4) are the best red spruce and Fraser fir sites because the ridgetops above protect the trees from windthrow. (4) Wildfires, both man- and naturally caused, greatly influence soil formation and subsequent vegetation at high elevations.

## THE MINERALOGY OF SOILS WITH SPODIC MORPHOLOGY IN THE SOUTHERN APPALACHIANS

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Soils with spodic morphology occur almost exclusively on feldspathic quartzites in the southern Appalachians. Another apparent requirement for the genesis of spodic morphology is geomorphic stability, including freedom from tree tip-over soil disturbance. The dominant vegetation associated with this morphology is spruce-fir with or without a rhododendron understory. This vegetation is shallow rooted and if the 0 horizon is thick enough, the vegetation is rooted in the organic horizon so when tree tip-overs occur, the mineral soil beneath is minimally disturbed. Soils with spodic morphology do occur under northern hardwoods, but did not form under that type of vegetation.

The mineralogy of the sand fractions is dominated by quartz and feldspars with only minor amounts of muscovite mica. Silt fractions have about equal amounts of quartz, feldspars, muscovite mica and hydrous mica. The clay fraction in all horizons contains no feldspar and less than 5% kaolinite. Gibbsite content in the clay fraction ranges from none in the A and E horizons to a maximum of 3% in the Bs horizon.

Intense chemical weathering destroys the feldspars in the upper soil horizons, which releases large amounts of aluminum and silica. The silica is evidently lost from the soil and does not reassociate with aluminum to form kaolinite in lower horizons. Muscovite is weathered into a regularly interstratified reactive vermiculite-smectite in the A and E horizons, but becomes hydroxy- interlayed with depth and forms a pedogenic chlorite in the lower horizons. This clay mineral distribution is nearly opposite to the clay mineral distribution in most other acidic forest soils without spodic morphology.

In other forest soils, aluminum released by primary silicate dissolution in the A and E horizons is rapidly incorporated into the vermiculite interlayer position in the upper soil horizons and is not translocated downward. In these soils, this inert hydroxy- interlayered vermiculite has its maximum occurrence in the surface and decreases with depth while the reactive vermiculite component has its minimum at the surface and increases with depth. The apparent reason for the most reactive clay minerals being at the surface in soils with spodic morphology is that the aluminum released by silicate destruction is chelated by special humic acids, a decomposition product of the spruce-fir needles, and translocated downward. There aluminum dissociates from the organic matter and either enters the vermiculite interlayer or forms gibbsite in lower subsoil horizons.

Mineral transformations and translocations in soils with spodic morphology seem to be related to the specific soil-forming process involved. The complexation and translocation of aluminum from surface horizons leaving reactive clay minerals behind may be useful in classifying soils with and without spodic morphology. Other soils in the southern Appalachians under spruce-fir or northern hardwoods but without spodic morphology, have different clay mineral distributions, and much larger amounts of gibbsite in subsoil horizons. The chelation of aluminum in some soils, which greatly increases its mobility, needs to be considered in current acid precipitation-soil effects research.

# ECOLOGICAL BOUNDARY EFFECTS ALONG THE GREAT SMOKY MOUNTAINS NATIONAL PARK BORDER

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The task of evaluating the effectiveness of conservation areas in preserving species and habitat diversity requires an assessment of the effects of activities and development outside these preserves on interior communities. The purpose of this study was to develop an objective methodology for evaluating areas along the Great Smoky Mountains National Park (GRSM) border in terms of spatial continuity of physical and biological site characteristics. An intensive field survey was conducted in two sites along the park border near Cosby, Tennessee. The first of these was an ecotonal area between a submesic cove hardwood forest and an open field. The second site constituted a gradual transition from a young cove hardwood forest to a mixture of woods, thickets, and small fields. Patterns of vegetation structure, physical site characteristics, and composition of plant and animal communities were compared between these two park border sites, and between the border sites and a control site within the park.

Cluster analysis of site variables from the first border area indicated sharp spatial disjunctions in 16 of 24 measured variables, including soil compaction, number and coverage of exotic species, small mammal species diversity, small mammal movements, and various structural vegetation parameters. These disjunctions were correlated spatially with the park border, indicating an ecological "boundary effect" resulting from the placement of the legal border. In the second border site, the increase in habitat heterogeneity outside the park was reflected in spatial disjunctions for such variables as rock coverage, moss coverage, and coverage of exotic understory species. Groupings of plots for total coverage of exotic species revealed an apparent spatial correlation with the legal park border; this correlation was due to a "front" of invading exotic species located approximately 75 m interior to the park border. The control site had no significant disjunctions between plot values for any of the variables measured, indicating that the distributions of values for all variables were unimodal.

Results of this study indicate that the methods used in sampling and analysis may be quite useful in the investigation of local boundary effects along the borders of nature preserves. This quantitative approach allows a comparison of the relative "strength" of boundary effects as measured by the coincidence of zones of disjunction for several

different variables. The use of a control site within the preserve is recommended as a means of detecting background levels of habitat heterogeneity, so that sampling methods can be fine-tuned to account for this natural variability.

## STUDIES ADDRESSING THE EFFECTS OF AIR POLLUTION ON THE SPRUCE-FIR FORESTS OF GREAT SMOKY MOUNTAINS NATIONAL PARK: AN OVERVIEW

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Our interest in possible air pollution-related effects to the spruce-fir forests of Great Smoky Mountains National Park (GRSM) began over two years ago. This concern was based on reports of widespread decline and occasional death of red spruce on Camels Hump Mountain in Vermont, reports of extensive forest damage to high elevation conifer forests in West Germany, evidence of unnatural suppression of annual growth rings of red spruce growing in GRSM, and the high level of pollutant loading in GRSM. The overall objective of this research project is to determine the biological and ecological condition of the spruce-fir forests with respect to possible decline and dieback of red spruce. There are four specific objectives:

1. Establish a system of permanent vegetation plots to describe existing stand conditions and evaluate changes over time;

2. Use the permanent plots as the framework for studies of ecological processes considered susceptible to change due to atmospheric deposition;

3. Conduct surveys to determine the extent and environmental relationship of possible decline and dieback symptoms of red spruce; and

4. Participate with researchers from other institutions in studies addressing cause and effect relationships between air pollution and forest decline.

Permanent vegetation plot locations are stratified by elevation (5000, 5500, 6000, and 6500 feet), topographic position (ridge, side slope, and draw), and general aspect (northwest to west and northeast to east). There are three plot replicates per stratification unit, resulting in 66 total plots.

In addition to comprehensive vegetation and site characterization data collection, soil samples from the $0_l$ (litter), $0_e$ plus $0_a$ (decomposed organic), and the upper 3 cm of mineral soil are being collected from three soil pits per plot. These samples will be analyzed for all standard chemical parameters and total elemental analysis. Twenty of these plots are being used for additional National Park Service-funded research. These include a small mammal survey, permanent plots for bryophytes and lichens, a dead organic matter biomass study, and a study of the extent and relationship to site and stand characteristics of annual increment suppression in red spruce. Beginning in the 1985 field season, the red spruce project will be incorporated into a Southern Appalachian Spruce-Fir Ecosystem Assessment Program, which is being coordinated by the Southern Appalachian Research/Resource Management Cooperative. This program involves researchers from five universities and three Federal agencies and initially will focus on collection of detailed baseline data to include site characterization and vegetation analysis, soil and plant tissue analysis, mycorrhizae, pest and pathogen quantification, compilation of historical data, aerial photography, atmospheric monitoring, dendrochronological analysis, and forest modeling and synthesis.

During field work in 1984, an unexpected and previously unreported foliar injury symptom was noted on understory red spruce. This symptom consisted of small necrotic lesions on the upper surface of needles. These lesions were usually not present on current season foliage but occurred with increasing severity for needles produced in each previous year. A preliminary study showed that the occurrence and severity of this injury was worse with increasing elevation. At 5000 feet elevation, 56 percent of the trees sampled showed moderate injury and 9 percent showed severe injury; at 6500 feet, 36 percent showed moderate injury and 62 percent showed severe injury.

# MODELING THE DYNAMICS OF A SOUTHERN APPALACHIAN SPRUCE-FIR FOREST IN RESPONSE TO ANTHROPOGENIC DISTURBANCES

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A forest succession model was developed from the FORET model of Shugart and West (1977) to simulate the stand dynamics of a spruce-fir forest in the Great Smoky Mountains. As in FORET, recruitment, growth, and death of individual trees on a gap sized tract are calculated and tabulated annually. The model was adapted to simulate the interactions of seven arboreal species common to the upper spruce-fir zone. In addition, recruitment algorithms were developed to simulate observed spatial relationships between incoming individuals and canopy trees.

The model was designed for studies of disturbances involving the decline of red spruce and/or Fraser fir populations. Old-growth forest responses to several potential disturbance regimes were simulated. Continuous balsam woolly aphid infestation results in a spruce–dominated forest. In the absence of fir, stand biomass recovery is slow and total stand density is reduced. A moderately severe spruce growth decline in the presence of an undisturbed fir population results in a fir-birch forest. However, in association with a fir population decline, the effects of spruce growth stress are diminished. The removal of both spruce and fir results in a hardwood forest with low total stand biomass.

## RESUPINATE FUNGAL ECOLOGY OF THE SPRUCE-FIR FOREST OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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An ecological survey of the resupinate fungi (Aphyllophorales; Basidiomycetes) from the spruce-fir forest of the park was accomplished. A total of 90 species, in 38 genera, are discussed in terms of habitats, substrates, wood rot, host trees, elevation, and distribution. Fungi usually occur in naturally disturbed areas with windbreaks and windthrows. *Hirschioporus* and stereoid fungi play an important role in decomposition of recently dead trees, and when they give way, corticioid fungi follow to colonize leftover substrates. Red spruce is the best host and is affected at mature and old stages. Fraser fir is another good host and is affected at younger stages. Elevational distribution of these fungi agrees with that of their host trees. The fungal flora of the spruce-fir forest is different from those of the cove forest of Cades Cove and the pine-hardwood forest of John Knox Camp.

## DEVELOPMENT OF A PLANT INDICATOR SYSTEM FOR MONITORING OZONE IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Atmospheric ozone ($O_3$) produced photochemically from oxides of nitrogen is expressed as visible plant injury, reduced photosynthate production and suppressed plant growth and yield in many agronomic and horticultural crop plants. During the spring, summer and fall months, daily mean concentrations of ambient $O_3$ range from 0.04 to 0.07 ppm. Hourly peaks of $O_3$ frequently exceed 0.12 ppm and may occasionally reach 0.15 ppm or higher in many rural and urban areas throughout the United States. Plant damage to $O_3$ is of particular concern to native and crop vegetation in California and in the central and eastern United States. Thus, $O_3$ stress to vegetation should be a continuing concern to the national parks in these areas and especially to the Great Smoky Mountains National Park (GRSM) because of the diverse plant ecosystems which are present in the park.

Various questions need to be addressed and include:

1. What are the ambient $O_3$ concentrations in GRSM?
2. What is the sensitivity of tree and understory species to $O_3$?
3. Do visible injury symptoms differ among tree species and understory herbaceous plant species and how are they recognized?
4. How can symptoms of $O_3$ be separated from similar symptoms of other abiotic and biotic stress?
5. Are plants susceptible at all ages and stages of development?
6. How does the microenvironment around plant- foliage influence sensitivity to $O_3$?
7. What methodologies are available for studying $O_3$ effects on vegetation in GRSM?

The assessment of the $O_3$ impact on the GRSM is dependent on answers to the above questions, as well as many others. To provide adequate assessment of $O_3$, instrument monitoring sites need to be established throughout the park at various elevations. Potential plant indicators need to be identified when it can be established that visible injury closely resembles $O_3$ symptomology. Some of the potentially more sensitive species need to be exposed to $O_3$ under controlled conditions to establish that the visible injury observed is the result of ambient $O_3$ stress. Once indicator species, both trees and understory species, have been identified, and visible $O_3$ injury confirmed experimentally, further injury assesssent on these species can be correlated with $O_3$ instrument monitoring data.

Ozone injury to a range of herbaceous and shrub understory species, as well as known $O_3$-sensitive tree species, has been observed and identified in GRSM. More effort should be given to an in-depth assessment and development of an $O_3$ monitoring system involving numerous plant indicator species and instrument monitoring.

# GROWTH AND DEVELOPMENT OF *GLYCERIA NUBIGENA* IN THE PRESENCE AND ABSENCE OF OZONE

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*Glyceria nubigena* was successfully grown from seed and propagated through division of plant growth into swards (clumps of grass) or individual plants. Vegetative methods of propagation were developed because of the time needed to grow large numbers of plants from seed. Following growth from seed or vegetative propagation, studies were initiated to determine the sensitivity of *G. nubigena* to $O_3$. Studies were also initiated to determine if different artificial and soil media influenced the growth and tillering of *G. nubigena* in the presence and absence of $O_3$.

Exposures to $O_3$ showed that *G. nubigena* was sensitive following daily exposures (5 da/wk) for 2 wks for only 3 hrs duration to 0.3 ppm $O_3$. Plants were also injured at 0.3 ppm $O_3$ for 6 hrs, 2 da/wk for 2 wks.

Further experiments showed that the dry biomass of *G. nubigena* decreased at 0.2 ppm $O_3$ and continued to decrease as $O_3$ was increased to 0.6 ppm. At 0.2 ppm there was a 2% decrease in dry weight and at 0.3 ppm the decrease was 8%. The weight per tiller, however, was affected by $O_3$ at 0.1 ppm following exposure for 6 hr/day, 5 da/wk for 5 wks. Foliar injury or necrotic stippling was visible at 0.2 ppm and was observed on approximately 10% of the leaf surface.

*G. nubigena* was grown on five growth media, including (a) Peat/Metro mix (1:1), (b) Peat/Metro mix (2:1), (c) (Peat/Metro mix/Soil 3(1:1):1, (d) Metro mix/Soil/Sand (1:2:1) and (e) Metro mix. Metro mix 220 is a commercial mixture of peat, perlite and vermicultite prepared by W. R. Grace & Co. and used in the bedding plant and nursery industry to grow a wide range of plants. *G. nubigena* plants grown on the different media were also exposed to 0.0, 0.1, 0.2 and 0.4 ppm of $O_3$, 6 hrs/day. The sensitivity of *G. nubigena* to $O_3$ was influenced by the growth medium. Visible foliar injury was observed at 0.1 ppm $O_3$ when *G. nubigena* was grown in 1:1 (Peat:Metro mix), 4:2:1 (Metro mix:Soil:Sand) and Metro mix. Plants were injured at 0.2 ppm $O_3$ when grown in each of the different media. The effects of $O_3$ averaged across all growth media were pronounced. There was a 10% and 5% loss in fresh and dry biomass, respectively,

at 0.1 ppm $O_3$. At 0.4 ppm $O_3$, the loss in fresh and dry biomass was 48% and 41%, respectively. *G. nubigena* grew best in the Peat:Metro mix (1:1) and the (Peat/Metro mix/Soil) (3(1:1):1) media. The growth of single plants of *G. nubigena* in different media compared fairly well with swards of *G. nubigena* grown in different media.

These studies have established that *G. nubigena* is sensitive to $O_3$ below the ambient air standard of 0.12 pm $O_3$. Experiments are in progress to study the sensitivity of *G. nubigena* to $SO_2$ and $SO_2$ + $O_3$.

## ESTABLISHMENT AND ASSESSMENT OF WHITE PINE BIOMONITORING PLOTS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Higher than acceptable levels of ozone ($O_3$) have been periodically measured at air pollution monitoring stations operated by the National Park Service. This project was initiated to utilize white pine as a bioindicator of ozone-induced injury. The objectives were to establish 35 permanent white pine-dominated plots (total of 525 trees) and to assess the ozone-specific visible plant injuries. Plots were established in the western portion of Great Smoky Mountains National Park in Tennessee and in the Cataloochee Valley in North Carolina. Plots were located in areas previously mapped by Miller in 1938 and resurveyed by DeYoung in 1979.

Branch collections were made in 30 plots using a 30-foot pole pruner. In five plots (all immediately adjacent to a paired pole-pruned plot) a high-powered slingshot was used to collect branches from over 75 feet. No significant differences in ozone injuries were observed using the T-Test procedure. The inference is that ozone injury symptoms may be reliabily detected from branches in the subcanopy (30 feet or lower). Each annual whorl was scored by percentage of ozone-induced injury, such as chlorotic mottle, tip necrosis, needle retention, and needle length (cm), as well as other forms of needle injury.

Sixty- six percent of the first- year needle whorls had no chlorotic mottle symptoms at all, but the percentage dropped to 15 and 18 percent, respectively, for the second- and third- year whorls. Approximately 20 percent of the 525 trees showed no evidence of chlorotic mottle. Approximately 8 percent of the white pine incurred ozone injury in the form of tip necrosis, predominantly on the first- year whorls.

Plans are set to resample the permanent plots again during the summer of 1985. From this baseline project, it is hoped that we can further delineate the impact of ozone on the white pine vegetation within the park.

## MAPPING ELEMENTAL CONCENTRATIONS IN GREAT SMOKY MOUNTAINS NATIONAL PARK WITH LICHENS

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- – James P. Bennett, Air Quality Division, National Park Service, Denver, CO

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*Hypogymnia physodes* (L.) Nyl., a foliose lichen, is being used to map the concentrations of elements associated with anthropogenic pollution in Great Smoky Mountains National Park. This species accumulates pollutants in concentrations proportionate to the ambient level of those pollutants, and therefore, provides a relative measure of air quality. European mapping studies and laboratory fumigations indicate that this species is moderately tolerant and can be an effective monitor in areas of elevated pollution.

A grid of 200 cells, each 3 x 3 $km^2$, was drawn over a map of the Great Smoky Mountains National Park. Collection sites were located within the cells on ridgelines between 1500 and 6500 ft elevations. The preferred substrate was *Betula lutea.* Other hardwood species, *Acer rubrum, Oxydendron arboreum,* and *Quercus* sp. were used when *B. lutea* was not present or did not bear *H. physodes.* In all, *H. physodes* was collected in 159 (79%) of the cells between February and October 1984.

Repeat collections were made in the first ten sites in the spring of 1985, roughly one year later. The specimens were examined and mechanically cleaned of bark and other materials.

Analysis of the specimens for 23 elements is in progress at the U.S. Geological Survey in Denver. Of the 159 cells successfully collected, 84 cells provided over 2 g of material, the amount required for analysis of all the elements. Of these elements, 22 heavy metals are being analyzed by Inductively Coupled Argon Plasmospectrophotometry (IGP). Sulfur content is being measured by high temperature combustion of the lichen material in a Leco furnace, oxidizing the elemental sulfur to sulfur dioxide.

## EFFECTS OF ACID PRECIPITATION ON THE SOIL SOLUTION CHEMISTRY AND BIOAVAILABILITY OF ALUMINUM AND ZINC IN THE SPRUCE-FIR FOREST OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK[1]

– – A. C. Stam, Graduate Program in Ecology, University of Tennessee, Knoxville, TN, and the Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

This research is designed to test the hypothesis that acid precipitation enhances the mobilization and bioavailability of toxic soil metals. General objectives are to determine (1) the influence of precipitation chemistry on the total concentration and speciation (organic complexes versus inorganic complexes plus ionic metal) of aluminum and zinc in the soil solution of the organic soil horizon; (2) the influence of precipitation chemistry on the bioavailability of Al and Zn (as inferred from plant tissue concentrations); and (3) the influence of the rhizosphere on the bioavailability of Al and Zn.

Two adjacent field plots were established in the Collins Shelter area in the Great Smoky Mountains National Park. The 3-m-diameter circular plots are isolated from ambient precipitation by plastic sheeting and are watered weekly with artificial precipitation of pH 3.5 (treatment) or pH 5.0 (control). Soil solution chemistry is monitored periodically following specific watering events throughout the growing season. This provides information on the effects of acid precipitation on the seasonal

variation in the soil solution chemistry of Al and Zn and on the changes in this solution chemistry following a given precipitation event.

Red spruce seedlings, which function as indicators of metal bioavailability, have been planted on the field plots. At the close of the experiment, the seedlings will be harvested and concentrations of Al and Zn in needles and roots will be measured. These data will be analyzed to determine if acid precipitation affects the uptake of soil Al and Zn. Several herbaceous species will be similarly monitored. A complementary greenhouse study of the effects of precipitation pH on the uptake of Al and Zn by red spruce is being conducted using artificial precipitation treatments of pH 3.5, 4.1, and 5.0.

The soil solution chemistry (total concentration and speciation) of Al and Zn in the rhizosphere of both greenhouse and field seedlings will be monitored for treatment effects. The soil solution chemistry data for bulk and rhizosphere soil and the plant tissue chemistry data will be evaluated to determine the influence of the plant on the uptake of Al and Zn.

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[1]This research was sponsored by the National Park Service, U.S. Department of the Interior, under Interagency Agreement NPS 0492-082-2 (DOE 40-1249-82) with Martin Marietta Energy Systems, Inc., under Contract No. DE-AC05-840R21400 with the U.S. Department of Energy.

# A SURVEY OF GROWTH-TREND DECLINE IN SPRUCE IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK AS INFLUENCED BY TOPOGRAPHY, AGE, AND STAND DEVELOPMENT

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Increment cores obtained from red spruce (*Picea rubens* Sarg.) at two FORAST study sites in the Great Smoky Mountains National Park (GSMNP) exhibited substantial differences in recent growth trends at the two sites. At Mt. Collins, a growth-trend decline began in the late 1960s, was followed by improved growth during the mid-1970s, then continued after 1979. In contrast, cores from Indian Gap exhibited a continuous decline since the early 1960s. Red spruce cores collected from various sites in the eastern half of the Smokies also showed a growth-trend decline beginning in the early 1960s (H. S. Adams, R. D. Rheinhardt and M. L. Lipford, unpublished data). An exploratory survey, therefore, was undertaken to determine the extent of red spruce decline in a limited area of the GSMNP and to examine possible variables associated with any decline. This study was designed to: (1) evaluate growth patterns of red spruce occurring at eight sampling sites within its major distributional range of elevation (approximately 1375 m - 1875 m) on each of two major exposures (northeast and southwest) on Mt. LeConte; (2) assess vigor status and extent of mortality of red spruce at these sites; (3) assess relationships of decline with size and/or age class by collecting cores from three size classes (10-25 cm DBH, 25-40 cm DBH, and > 40 cm DBH) of red spruce in a mixed size/age stand at Mt. Sterling; (4) determine growth patterns for the fifty years prior to death of recently dead red spruce; and (5) evaluate growth patterns of planted Norway spruce (*Picea abies* (L.) Karst.) at two elevations (approximately 1485 m and 1325 m). Mean ages of trees at study sites ranged from 38 years for Norway spruce to 258 years for red spruce.

Subjective estimates of vigor status of red spruce were similar for all elevations on the southwest slope of Mt. LeConte, but greater variation and more severe foliage loss were recorded on the northeast slope. Least healthy trees were observed at 1720 m on the northeast slope. Mortality of red spruce on the southwest slope (8.7 percent) was twice that on the northeast slope. Mean growth of trees during the 1972-1981 decade

was compared to mean growth of the same trees during a reference period (1932-1951). At 1385 m elevation, growth did not differ much between the two periods, but growth decreased during the later decade by around 18 percent at 1540 m, 30 percent at 1720 m, and > 50 percent at 1845 m. The growth decreases for the 1972-1981 period exhibited a greater relationship to elevation than to either age or substrate. A growth-trend decline that occurred during a drought period in the 1950s was evident in biweight means at all sites and was followed by recovery of growth. The more recent decline exhibited at the higher elevations, unlike declines reported for the northern and mid-Appalachians, does not coincide with drought.

A similar pattern of growth decline beginning in the 1960s was exhibited by all size classes of red spruce at Mt. Sterling, although the decline in the smallest trees has been followed by an increase in growth since the mid-1970s. This recent "release" probably is due to death of the surrounding Fraser fir (*Abies fraseri* (Pursh) Poir.). Abrupt transition to unusually narrow growth increments was exhibited more frequently by the oldest trees (64 percent) than by the youngest (15 percent).

Cores from the dead red spruce did not exhibit a sudden onset of decline, but rather a general slowing of growth throughout their last fifty years. Mean annual increment size during that period was less than 1 mm and had decreased to an average of < 0.5 mm at time of death. Growth increments of live red spruce in areas of severe decline on Mt. LeConte and Mt. Sterling also have decreased to less than 1 mm during the last two decades.

Growth-trend decline patterns also were apparent in much younger (approximately 40 year-old) planted Norway spruce at both elevations at which it was surveyed commencing in the early 1960s. The decline at the higher elevation was more severe. Onset of decline was somewhat earlier than that observed for red spruce on Mt. LeConte or Mt. Sterling, but possibly was influenced by stand dynamics of these younger Norway spruce.

In summary, growth-trend declines were found in both species of spruce at all sites in the three localities studied in the GSMNP with the exception of red spruce below 1540 m. Growth decreases were considerably greater at higher elevations. Older individuals at Mt. Sterling were more likely to exhibit abrupt transition to unusually narrow increments, but younger and smaller trees have recovered from the decline

pattern. Trees at higher elevations on Mt. LeConte and older trees at Mt. Sterling are presently exhibiting a rate of growth comparable to that occurring in the last fifty years of individuals which have recently died. Existence of a growth trend decline in young planted Norway spruce demonstrates the pervasiveness of whatever stress or combination of stresses is contributing to growth trend declines in spruce in the Smokies.

## VISIBILITY AND OTHER AIR QUALITY MEASUREMENTS MADE AT GREAT SMOKY MOUNTAINS NATIONAL PARK, 1980-1983

- - Lawrence M. Reisinger and Ralph J. Valente, Research Section, Tennessee Valley Authority, Muscle Shoals, AL

In mid-1980, the Tennessee Valley Authority, in cooperation with the Environmental Protection Agency and the National Park Service, established the Look Rock visibility and air quality monitoring station at the western edge of the Great Smoky Mountains National Park (GSMNP) as a primary visibility and air quality monitoring station for the eastern United States.

Several visibility monitoring techniques were employed, including slide photography, teleradiometry, and nephelometry. To correlate visibility observations with factors influencing visibility, ambient air quality and meteorological data were also collected.

Results indicate that visibility in the GSMNP is poorest during the summer months when, coincidentally, the greatest tourism occurs. While the annual median visibility as inferred from nephelometry measurements is about 65 kilometers (km), the summertime median visibility is less than one-half this value at 24 km. Visibility at the GSMNP is poor when compared with Federal land-use areas in the western United States where median annual visibilities are more than 150 km.

Regional haze is the most frequent cause of visibility impairment in the park, especially during the summer months. Slide photographic records indicate that annually, haze is the principal obscuring phenomenon 65 percent of the time, but during the summer months, haze occurs about 85 percent of the time.

Ozone, principally a manmade pollutant, is a key indicator of the complex photochemical process that leads to the formation of the fine particles. During the summers of 1980 and 1983, periods which, because of extensive air stagnation and generally hot and dry weather, were especially conducive to the formation of photochemical air pollution, ozone levels greater than the National Ambient Air Quality Standard (NAAQS) were recorded on 23 days. Poor regional visibility also occurred on many of these days.

## AIR QUALITY MONITORING IN GREAT SMOKY MOUNTAINS NATIONAL PARK

-- David Silsbee, Uplands Field Research Laboratory, Great Smoky Mountains National Park, Gatlinburg, TN 37738

Air quality monitoring in Great Smoky Mountains National Park is currently concentrated at Look Rock at the western end of the park. Established in 1980 by the Tennessee Valley Authority (TVA), the Look Rock station is now operated by the TVA, the State of Tennessee, and the National Park Service. Parameters monitored include ozone, nitrogen oxides, visibility, total suspended particulates, mass and elemental composition of two size fractions of particulate matter, and meteorological parameters. Precipitation chemistry has been monitored since 1981 at a National Atmospheric Deposition Program (NADP) site at Elkmont.

Additional ozone monitors are being established in 1985 at Cove Mountain (elev. 4100 ft) and Clingmans Dome (elev. 6600 ft) in order to evaluate the representativeness of the Look Rock site. Additional high elevation monitoring will be conducted as part of an Electric Power Research Institute project conducted by Oak Ridge National Laboratory scientists in the park. Monitoring will include precipitation chemistry, cloud water chemistry, aerosol and particulate water composition, and nitric acid vapor and sulfur dioxide concentrations. Deposition rates as well as ambient concentrations will be estimated.

# SPATIAL AND TEMPORAL PATTERNS IN STREAM CHEMISTRY IN AN ACIDIC STREAM IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK[1]

R. R. Turner, M. A. Bogle, J. W. Elwood, P. J. Mulholland, A. V. Palumbo and D. M. Genung, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

Walker Camp Prong, located in the Great Smoky Mountains National Park, is being used as a site for research on the biotic effects of acidity and dissolved aluminum in low-order woodland streams. Results of monitoring and experimental manipulations are being used to test the general hypothesis that biotic responses to stream acidification are most pronounced in the headwaters and decrease downstream in response to chemical gradients that expand longitudinally during episodic inputs of acid and aluminum from the watershed.

The main stem of Walker Camp Prong exhibits well-defined longitudinal gradients in pH, alkalinity, aluminum, and other stream water constituents. These gradients are driven in part by the presence of pyritic bedrock (Anakeesta Formation), which occurs at the higher elevations in Walker Camp Prong and which yields acidity when exposed to oxidation by landslide activity. In spite of this internal source of sulfate, nitrate contributes nearly equally to the total equivalent weight of acid anions. In addition, several adjacent tributaries offer contrasts in stream chemistry, which are useful in biological experiments directed at identifying causal factors. Spatial variations in base flow stream pH span the range from 4.5 to 6.5, while monomeric aluminum varies from 0.5 to 11 μmol/L. Temporal variations in stream pH and aluminum span similar ranges and are generally larger at downstream sites than at upstream sites, reflecting the downstream expansion of acidification during storm runoff. In comparison with similar woodland streams in the Adirondacks, Walker Camp Prong has lower concentrations of dissolved organic carbon and fluoride, two aluminum-complexing ligands which reduce the relative toxicity of aluminum to fish. Thus, for similar concentrations of monomeric aluminum, stream water from Walker Camp Prong should be more toxic to biota than Adirondack stream water.

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[1]Research supported by the Electric Power Research Institute under contract No. RP2326-1 with Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., under contract No. DE-AC05-840R21400 with the U.S. Department of Energy.

# RESULTS OF CONTINUOUS PH MONITORING OF AN ACIDIC STREAM IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK[1]

- - Mary Anna Bogle and Ralph R. Turner, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

As part of a research project on the effects of acidification on low-order woodland streams, a continuous monitoring system for measuring pH, conductivity, temperature, and stream stage was installed (February 1985) on a low-order, low-ionic-strength stream (Walker Camp Prong) in the Great Smoky Mountains National Park. Periodic calibration checks of the system established that pH measurements by the monitor were within 0.12 pH units of an independently measured value.

Results to date show that the magnitude and duration of pH depressions are related to both the intensity and duration of episodic events; i.e., pH is inversely correlated with stream stage. Intense storms of short duration resulted in pH depressions of a full unit, but pH (and stage) returned quickly to base flow values, whereas low-intensity storms of long duration resulted in moderate pH depressions of long duration. An initial rise in stage resulted, in most cases, in an initial rise in pH, possibly attributable to alkaline runoff from the nearby road (U.S. 441), followed by a sudden drop in pH. Continuous pH readings at base flow revealed diurnal fluctuations of usually 0.3 to 0.4 pH units, with pH peaking during early afternoon (1:00 - 2:00 p.m. EST). Preliminary measurements of dissolved inorganic carbon (DIC) in stream water taken over the same period as diurnal pH fluctuations showed a depletion in DIC corresponding to the increase in pH, suggesting that the diurnal increase in pH of this poorly buffered stream (alkalinity $\leq$ 20 $\mu$eq/L) is attributable to depletion of $CO_2$ through photosynthetic activity. Stabilization of pH during late afternoon and at night indicates that an equilibrium between outgassing of $CO_2$ and production of $CO_2$ has been reached, thus preventing the continued accumulation of carbonic acid and the further reduction in pH. Because diurnal changes in pH from photosynthesis and respiration may be substantial in streams of low alkalinity such as Walker Camp Prong, the time of day that pH is measured becomes important in interpreting pH trends and differences.

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[1]Research supported by the Electric Power Research Institute under contract with Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., under contract No. DE-AC05-840R21400 with the U.S. Department of Energy.

# EFFECT OF STREAM ACIDIFICATION ON PERIPHYTON COMMUNITY COMPOSITION, ABUNDANCE, AND PRODUCTIVITY[1]

-- P. J. Mulholland, J. W. Elwood and A. V. Palumbo, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN

R. J. Stevenson, University of Louisville, Louisville, KY

Periphyton community composition, biomass, and productivity were measured along a pH gradient in Walker Camp Prong, a high elevation stream in the Great Smoky Mountains National Park. The periphyton community was dominated by small Chrysophytes and blue-green algae at sites with baseflow pH > 5.7 and by larger diatoms and green algae at sites with pH < 5. Although cell numbers per unit surface area decreased with decreasing pH, biovolume and chlorophyll a per unit area increased with decreasing pH. Primary productivity per unit surface area also increased with decreasing pH. This was a result of the increase in periphyton chlorophyll because chlorophyll-specific rates of production were lowest at the most acidic site.

Manipulative experiments (in situ) indicated that water quality changes associated with stream acidification may have a direct effect on periphyton productivity. Short-term transplant experiments (1-2h) of periphyton at highly acidic (pH 4.9) and circumneutral (pH 6.8) sites indicated no immediate effect on chlorophyll-specific productivity, but a negative effect of low pH on chlorophyll-specific ATP level. Short-term addition of $PO_4$ resulted in a reduction in chlorophyll-specific productivity at a highly acidic site, which is consistent with the presence of strong phosphorus limitation. In addition, manipulations involving a reduction in dissolved inorganic carbon (DIC) to < 0.3 mg $L^{-1}$ resulted in reduced chlorophyll-specific productivity. Because concentrations of DIC are generally 0.3-0.4 mg $L^{-1}$ (with values as low as 0.2 mg $L^{-1}$ measured) at the sites with pH < 6, periphyton at these sites may be inorganic carbon limited at times.

Despite the evidence of some negative effects of increased acidity on periphyton, periphyton biomass (chlorophyll a and biovolume) and productivity increased with increasing stream acidity. We believe that this is the result of reduced grazing by stream invertebrates at increased levels of stream acidity. Densities of grazing

invertebrates are markedly lower at the highly acidic stream sites. Our preliminary conclusion is, therefore, that acidification in Walker Camp Prong has had a greater direct impact on herbivory than on primary productivity.

[1]Research supported by the Electric Power Research Institute under contract with Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., under Contract No. DE-AC05-840R21400 with the U.S. Department of Energy.

## BACTERIAL DYNAMICS IN AN ACIDIC STREAM, WALKER CAMP PRONG, GREAT SMOKY MOUNTAINS NATIONAL PARK

A. V. Palumbo, University of Tennessee and Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

We measured the biomass and productivity of bacterial communities associated with rocks, sediment, and water in Walker Camp Prong and some of its tributaries, and in other acidified and circumneutral streams in eastern Tennessee and western North Carolina. The headwaters of Walker Camp Prong are acidified and have elevated aluminum concentration; pH depressions and increases in aluminum concentration occur downstream during storms. The biomass and heterotrophic activity of bacteria in stream sediments were not related to the pH of the overlying water but were correlated with the organic content of the sediment. Direct counts of bacteria in the water column indicated no significant relationship between the number of bacteria and the pH or phosphorus concentration, but did indicate a correlation between the number of bacteria and seston concentrations. Adenosine triphosphate (ATP) levels, a measure of microbial biomass, were significantly higher on rocks in an unacidified tributary, Cole Creek, than at Walker Camp Prong sites subject to chronic or periodic acidification. Epilithic bacterial productivity, as measured by $^{3}H$-thymidine incorporation into DNA, was significantly higher at high-pH sites in Cole Creek and Walker Camp Prong than at low-pH sites. Transplants of rocks from high-pH sites to low-pH sites for periods of up to 48 h did not significantly reduce bacterial production. Therefore, the effect of pH, or of associated high aluminum concentrations, must be long term or indirect. The density of invertebrate grazers is lower at the low-pH, high-aluminum sites; the

reduced grazing pressure may negatively influence bacterial production at those sites.

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[1]Research supported by the Electric Power Research Institute under contract with Oak Ridge National Laboratory, operated by Martin Marietta Energy Systems, Inc., under contract No. DE- AC05- 840R21400 with the U.S. Department of Energy.

## WATER QUALITY IN STREAMS OF THE BIG SOUTH FORK NATIONAL RIVER AND RECREATION AREA OF TENNESSEE AND KENTUCKY

- - Michael Rikard, Hydrologist, Big South Fork National River and Recreation Area, Oneida, TN 37841

Sam Kunkle, Hydrologist, Water Resources Division, National Park Service, Fort Collins, CO 80523

Coal mining, oil and gas extraction, sewage releases, and agricultural activities within the boundaries of Big South Fork National River and Recreation Area are affecting the water quality of its streams. In November 1982 a water quality monitoring program was initiated in the recreation area to evaluate the water quality of the streams, identify polluted streams, locate major sources of pollution, and determine the background levels of water quality in unaffected streams. Samples were collected at 34 sampling sites on a monthly (or in some cases a bimonthly) basis and were analyzed for 15 constituents, including indicators of acid mine drainage, sewage discharge, and watershed disturbances.

The data gathered for the November 1982 to October 1984 monitoring period allowed grouping of streams into the following five major categories: (1) clean with sandstone basin, (2) clean with limestone basin, (3) slightly polluted, (4) moderately polluted, and (5) severely polluted. The "clean" category streams contained low bacterial counts, low levels of metals, neutral pH values, and low acidity, and they supported trout or other fish populations. At the other extreme, the "severely polluted" streams often exhibited fecal coliform concentrations above 100 colonies per 100 ml, iron levels above 0.2 mg/1, acidity greater than 30 mg/1, manganese over 0.5 mg/1, and pH values as low as 3.9.

# PRODUCTION DYNAMICS FOR AQUATIC INSECTS IN PRISTINE AND SURFACE MINED STREAMS IN THE HEADWATERS OF BIG SOUTH FORK

-- J. Schiller and G. L. Vaughan, Zoology Department, University of Tennessee, Knoxville, TN 37916

Life history and production dynamics of several species of aquatic insects are compared in two first order woodland streams of the Big South Fork watershed. One stream, Bruce Creek, was mined prior to the Surface Reclamation Act (ca. 1968) and approximately three percent of its drainage area has been affected. The other stream, Crabapple Creek, serves as a "pristine" reference. Data are based on benthos samples collected monthly from January 1984 through May 1984. Sixteen square-foot surber samples were collected from riffle areas of each stream, but the preliminary results reported here are based on four samples analyzed per stream. Production rates were calculated by the size-frequency (Hynes) method. The sampling period includes most of the period of growth for many fast seasonal species such as *Amphinemura* spp. and *Ephemerella dorothea* and a significant fraction of the total growth of many other species. Thus, relative comparisons between streams can be made.

Length-weight relationships for each species were obtained by least squares regression using individuals of that species when possible or the next closest taxonomic level otherwise. Individual insects were dried, dessicated, and weighed to the nearest microgram. Specimens used in the length-weight analysis were obtained from several qualitative samples of local streams. Total production is similar in the two streams. Relative production varies according to taxonomy and trophic strategy. Most Ephemeroptera exhibited lower production in Bruce Creek while the opposite was true of Plecoptera. *Epeorus dispar* is the exception to this pattern among the Ephemeroptera. The water beetles *Psephenus herricki* and *Ectopria nervosa* were more productive in Crabapple, as were the stone-dwelling Trichoptera in the genus *Neophylax*. However, the net-spinning Trichopteran *Diplectrona modesta* exhibited higher production in Bruce. The Dipteran, *Prosimulium*, also a filter feeder, had similar production in both streams.

These results concur with the basic pattern of physical and biological effects reported in earlier studies. Physical water parameters indicate continued degradation of water quality in Bruce Creek. Overall productivity of aquatic insects in Bruce Creek is

similar to a pristine stream, Crabapple Creek, indicating the relative changes in species composition and productivity may be permanent. Assuming surface mining for coal has similar effects in other first order tributaries of the Big South Fork and given the large amount of surface area yet to be mined in this river system, permanent alteration of its aquatic insect fauna is likely.

## ASSESSMENT OF THE BIOLOGICAL IMPACT OF SURFACE MINING FOR COAL IN PRIMARY WATERSHEDS IN THE UPPER DRAINAGE OF THE BIG SOUTH FORK

- - G. L. Vaughan and J. Schiller, Zoology Department, University of Tennessee, Knoxville, TN

The Department of Energy supported through the Civil Engineering, Geology and Zoology Departments of the University of Tennessee a comprehensive and multidimensional research program examining the environmental aspects of surface mining of coal in primary watersheds of the upper Big South Fork drainage. The total project, spanning nearly seven years, was designed to provide an extensive characterization of hydrologic, water quality, geochemical, and biological regimes so that interrelationships could be tested and predictive models could be developed directly through examination of subcomponents of the primary watersheds affected by mining activity.

Since the research spanned progressive changes in strip mine regulations and, subsequently, reclamation, the data can be used in part to assess the effectiveness of changes in mining procedures, including the implementation of the current back-to-contour methods. This presentation deals mainly with the biological effects of surface mining for coal. The data base is so extensive that it would be impractical to discuss them in detail here. The hydrologic and biological data have, however, been organized into an extensive computerized data base available upon request for the cost of duplicating computer tape or xeroxing hard copy.

In general, a series of summarizing statements can be made. First, if not confounded by deep mine operations, surface coal mines in the New River watershed in Scott, Morgan, Campbell and Anderson counties invariably produced alkaline drainage,

not acid as might be presumed. Secondly, analysis showed that changes in biological communities of diatoms, benthic insects and fishes were directly attributable to factors associated with greatly increased stream flow, such as a substrate scouring, siltation and increased bed load. Changes in biota were not correlated with changes in pH. Thirdly, it must be noted that in no case (including reclamation to the most current federal requirements) were aquatic biological communities not severely impacted by surface mining. One encouraging finding was, however, made. In examining a series of streams which had been mined in the past, it was determined that recovery of insect and fish communities can ensue within a relatively short 15–20 years, provided that the watershed remains undisturbed after mining, that there is no confounding acid input, and finally that refugia are present to provide organisms for recolonization. The extent of mining in some areas is so great, however, that the refugia are absent and the risk of species loss or extinction is high. Regional mining plans must be developed to prevent the pace of disturbance from outdistancing the ability of biological communities to recover. Coordinated mining plans withholding certain areas as refugia until others have recovered, along with improved extraction techniques, will minimize impact and optimize recovery of aquatic biological communities.


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