Annotated Bibliography of Publications on Watershed Management and Ecological Studies at Coweeta Hydrologic Laboratory, 1934-1994

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Introduction

This bibliography is a modification and update of previous compilations of research results at Coweeta. It was prepared in response to requests for information from scientists, educators, students, land managers, and policymakers. The bibliography contains annotated citations of papers plus a separate section listing university theses and dissertations. Papers were included if authored by Forest Service and other Federal scientists, university faculty and students, or other individuals who conducted research in the Coweeta basin, utilized Coweeta data in their analyses, or received funding or other assistance from the Southeastern Forest Experiment Station. The bibliography spans 60 years of research at Coweeta from 1934 through part of 1994; it also includes papers on forest influences written at the Station before the establishment of Coweeta.

The citations are arranged alphabetically by author and date. We regret that we cannot furnish most of these publications, but they are available at university libraries, and some reprints may be available from the senior authors. The subject index keys the page number of each citation to one or more subject categories.

Coweeta's early emphasis on how land management practices affect the hydrologic cycle has evolved into a broader interdisciplinary effort that couples hydrology within an ecosystem context. The following account of the program, partially from a paper on the history of Coweeta by Douglass and Hoover (1988), summarizes the present research effort and then traces the progression of events that contributed to Coweeta's research history.

The Current Research Program

The mission of the Research Work Unit (RWU) at Coweeta is to evaluate, explain, and predict how water, soil, and forest resources respond to management practices, natural disturbances, and the atmospheric environment; and to identify practices that mitigate impacts on these watershed resources. The approach to this mission is to meld theory development, experimental testing, modeling, and applications – usually on a landscape scale – where the watershed is the unit of both hydrologic and ecosystem investigation.

Research combines short-term (5 years or less) with long-term (decades) studies on the responses of forested watersheds to various kinds of natural and human-induced disturbances. Although much of the research takes place within the Coweeta basin, some studies are installed in other forest ecosystems in the region. Current topics of emphasis include continuing analyses of long-term hydrology, nutrient cycling, and productivity responses to management practices and natural disturbances (drought, flood, insects); assessment of prescribed burning effects on the forest environment; an interdisciplinary, interinstitutional implementation of Ecosystem Management on the national forests; effects of climatic change on productivity for the entire South; impacts of atmospheric deposition on forest processes and ecosystems; the cumulative effects of land use practices on water quality; physiological studies of forest carbon balance and competition; and biodiversity.

Process-level studies on Coweeta's undisturbed watersheds provide the control for evaluating ecosystem responses to disturbances. Our goal has been to integrate individual research efforts into a holistic concept of watershed response across a range of time and space scales.

The research program encompasses a broad array of cooperative studies that averages about 30 projects annually with about 45 graduate students and 40 senior investigators. These studies support the RWU mission and greatly expand the scope and depth of scientific effort at Coweeta. The centerpiece of the cooperative effort is the Long-Term Ecological Research (LTER) Program with the University of Georgia, begun in 1980 and funded through the National Science Foundation. Participation in the LTER network evolved from earlier cooperative ecosystem studies between Coweeta and the University.

This bibliography not only reflects results from Coweeta participation in LTER, but also from many other cooperative efforts including the U.S. International Biological Program, U.S. Man & Biosphere Program, the Integrated Forest Effects project, the National Atmospheric Deposition Program, the Whole-Tree Harvesting Project, and numerous other studies with scientists from universities and agencies.

The Past Research Program

Interest in the forest environment in the Southeast began more than 90 years ago with lively speculation about the influence of forests on climate and public health, and on soil and streamflow. In a widely-read 1909 government publication, Major-General Chittenden of the Mississippi River Flood Control project argued that forests were of no significance in flood control. The framers of the Weeks Act of 1911, which led to the creation of the national forests, did not concur in this view. The controversy reached a high pitch at the time of the disastrous 1927 flood on the Mississippi River. Almost everything written on the favorable effects of forests on streamflow was under scrutiny.

On July 1, 1921, the U.S. Department of Agriculture established the Appalachian Forest Experiment Station (now called the Southeastern Forest Experiment Station) in Asheville, NC. When active research began in 1926, the program included silviculture, reforestation, and management of forests, as well as forest protection, forest economics, and streamflow and erosion control.

At that time, eastern forests were extensively grazed by livestock. Steep mountain land was cleared and planted with corn. Logging was done by subcontractors who had little regard for erosion from roads and skid trails. Erosion on wornout and abandoned land in the Southeast was regionwide. Such land was not wanted by private individuals and could be bought for delinquent taxes. At the time, the rank and file of professional foresters knew little about forest effects on climate and soil. They were unaware of such streamflow variables as total water yield, maximum peak discharge, minimum flow dependability, or sediment loading.

Fortunately, E.N. Munns, of the USDA Forest Service Branch of Research, had observed and written about land erosion in California prior to his assignment to Washington. Supported by E.H. Clapp, then Chief of Forest Research, Munns became an effective advocate of better land use and of more in-depth research into influences of forests on water yield. In the mid-1920's, the Branch of Research requested a Civil Service examination for ecologists with Ph.D. degrees and selected two applicants. One of them, Charles R. Hursh, began work at the Appalachian Station in 1926 and directed the Station's Division of Forest Influences until his retirement in 1954.

Some of the earliest work dealt with erosion control and methods of stabilizing soil on roadbanks and abandoned agricultural land, and with the study of forest humus types of the region. At the Bent Creek Experimental Forest near Asheville, plots were established in 1932 to study surface runoff from five representative types of forested or agriculture cover, and an infiltrometer was first used successfully with artificial rainfall. These early studies led to an examination of water movement through the soil profile and to the need for complete watershed instrumentation to provide continuous measurements of streamflow and precipitation.

Based on this need, Hursh sought suitable areas conducting comprehensive studies on watershed management. John Byrne, Forest Supervisor of the Nantahala National Forest, suggested a number of possible sites, and the Coweeta drainage basin near Franklin, NC, was finally selected as the most suitable. In 1933, 3,900 acres (later increased to 5,750 acres) of the Nantahala National Forest were set aside as the Coweeta Experimental Forest. Station Director C.L. Forsling later issued instructions that no manipulations of the forest cover were to take place at Coweeta until after a period of standardization of the gaged watersheds. He assigned full responsibility for administration of the Coweeta basin to the Division of Forest Influences.

Thus, the stage was set for a greatly expanded program in watershed management research. Programs of the Civilian Conservation Corps and the Public Works Administration during the Great Depression years provided the manpower and funds for expansion of research activities. An intensive program of weir construction began in 1934 along with a network of 56 standard rain gages, numerous ground-water wells, and meteorological stations.

By 1939, calibration of watersheds at Coweeta was far enough along on some catchments to begin treatments, and a period of experimentation began. Since then, scientists have conducted a variety of watershed experiments at Coweeta. Early studies documented the harmful effects on soil and water resources by mountain farming, woodland grazing, and unrestricted logging. These early land-use demonstrations were publicized in the highly successful film "Waters of Coweeta." Scientists designed and implemented water-yield experiments to measure effects on streamflow of complete or partial forest cuttings and conversion from one type of cover to another. The knowledge gained in these early experiments was the basis for a pilot test of intensive multiresource management of Southern Appalachian forests and has provided guidelines for watershed management and best management practice standards on public and private lands alike. More recent experiments utilizing cable logging methods and advanced forest road designs have demonstrated improved methods for managing steep mountain lands to minimize damage to soil and water.

The culmination of the first 50 years of research at Coweeta was synthesized at a 1984 Symposium at the University of Georgia and later published in a well received book entitled "Forest Hydrology and Ecology at Coweeta."

Annotated Bibliography of Publications on Watershed Management and Ecological Studies at Coweeta Hydrologic Laboratory, 1934-1994

1. **Abbott, D. T.; Crossley, D. A., Jr. 1982.** Woody litter decomposition following clear-cutting. Ecology. 63: 35-42.

Unconfined *Quercus prinus* woody litter of three size classes (0-1, 1-3, and 3-5 cm diameter) was placed on forest floors of a control hardwood watershed and on mesic and xeric sites of a clearcut watershed at Coweeta. Exponential decay coefficients for mass loss on the control were 0.1524, 0.1728, and 0.0912 per year for 0-1, 1-3, and 3-5 cm branches, respectively. Coefficients for 0-1, 1-3, and 3-5 cm branches were 0.1752, 0.0756, and 0.1644 per year on the mesic site and 0.0456, 0.0948, and 0.0377 per year on the xeric site. The effect of site differences on decomposition rate was greater than the effect of diameter, although an inverse relationship between diameter and decay coefficient is suggested. Time in the field, temperature, moisture, and microarthropod abundance also appeared to influence decomposition rate.

2. **Abbott, David T.; Seastedt, T. R.; Crossley, D. A., Jr. 1980.** The abundance, distribution and effects of clear-cutting on Cryptostigmata in the southern Appalachians. Environmental Entomology. 9: 618-623.

Oribatid mites were sampled from deep soil, soil cores, litter bags, and woody litter on a clearcut and adjacent control hardwood watershed at Coweeta. The inclusion of woody litter and deep soil samples caused the total number of genera found to reach 72, as opposed to the 37-42 genera range reported in other studies. The more common genera were assigned to three habitat types based on stratification data. The fauna was similar to those of other holarctic study sites. Sampling a greater variety of habitat types yielded a richer fauna than intensive sampling of a few habitat types. Clearcutting caused a reduction in numbers and a shift in faunal dominance. This effect is attributed to temperature-humidity phenomena rather than to food availability.

3. **Anderson, M., reviewer. 1989.** Forest hydrology and ecology at Coweeta. Forestry. 62(2): 175.

A review of the Coweeta Symposium volume.

4. **April, Richard; Keller, Diane. 1990.** Mineralogy of the rhizosphere in forest soils of the eastern United States. Biogeochemistry. 9: 1-18.

Chemical and mineralogical studies of forest soils from six sites in the Northeastern and Southeastern United States, including the two Integrated Forest sites at Coweeta, indicate that soil in the immediate vicinity of roots show marked differences in physical characteristics, mineralogy and weathering compared to the bulk of the forest soil. Mineral grains are affected mechanically, chemically and mineralogically by the invading root bodies. The edges of mineral grains abutting root surfaces were significantly more fractured. Chemical interactions between roots and minerals included precipitation of amorphous aluminum oxides, opaline and amorphous silica, and calcium oxalate within the cells of mature roots and possible preferential dissolution of mineral grains adjacent to root bodies.

5. **Autry, A.R.; Fitzgerald, J.W. 1990.** Sulfonate-S a major form of forest soil organic sulfur. Biology and Fertility of Soil. 10: 50-56.

Several forests of varying elevations, soils and vegetation were studied to evaluate the relative importance of sulfonate S, amino acid S, and ester sulfate as constituents of soil organic S. Sulfonate S exceeded 40 percent of total S in O1 horizon of all but one site examined, and comprised at least 50 percent of total S in the O2 horizons of 14 out of 18 study sites. Sulfonate pool sizes, on a percentage basis, tended to decrease with increasing sample depth within the mineral horizons, but sulfonate S was still a major form of organic S in the C horizon. Amino-acid S pool sizes were lower than those for sulfonate and decreased with increasing depth at all but one site. Ester sulfate pool sizes were generally less than those of sulfonate S and greater than those of amino-acid S in the O1, O2, and A horizons. In the intermediate and lowest soil horizons, ester sulfate levels exceeded those for sulfonate S in half the sites. Thus, sulfonate S is a major form of organic S in forest soils, irrespective of depth.

6. **Autry, Andrew R.; Fitzgerald, John W. 1991.** Organosulfur formation in forest soils: site comparison of kinetic parameters. Soil Biology and Biochemistry. 23(7): 689-693.

Soil samples were collected at various depths in forested sites that should have different sulfate deposition histories. Saturation potentials, based on the V max for SO_4-S incorporation into organic matter, were found to decrease with increasing depth in 8 out of 12 sites. Estimation of the SO_4-S concentration required to saturate a given horizon was made and, irrespective of depth, a forest located near a coal-fired powerplant was the most saturated whereas samples from forests located in relatively non-polluted areas were generally the least saturated. This latter parameter was found to decrease with increasing

depth in 6 out of 12 sites. Turnover times for the recently formed organic S exceeded 10^3 h in approximately half of the sites at all soil horizons. These results indicate that no significant change in the recalcitrance of the newly formed organic S occurred with increasing depth.

7. **Autry, Andrew R.; Fitzgerald, John W. 1993.** Relationship between microbial activity, biomass and organosulfur formation in forest soil. Soil Biology and Biochemistry. 25(1): 33-39.

The capacity to form organic S was determined for micro-organisms present in soil samples, collected from different depths of an eastern white pine forest. Inhibitors of eukaryotes, gram-negative prokaryotes, and aerobically respiring prokaryotes and eukaryotes were used to assess the relative contribution of each group to organosulfur formation over a wide range of added sulfate. Values for microbial biomass and activity were estimated and correlated with organosulfur formation potentials at various soil depths. Most of this latter activity, regardless of concentration of added sulfate, was mediated by aerobically respiring prokaryotes. In each horizon, however, increasing concentrations of sulfate induced a shift in the physiological types of microbial populations responsible for organic S formation. ATP pool sizes and native soil respiration rates exhibited positive relationships with organosulfur formation with concentrations of sulfate added.

8. **Autry, Andrew R.; Fitzgerald, John W.; Caldwell, Penny R. 1990.** Sulfur fractions and retention mechanisms in forest soils. Canadian Journal of Forest Research. 20: 337-342.

Organic S was found to constitute over 78 percent of total S in the uppermost mineral (0-20 cm; A,E) horizons. Several forests of varying elevation, vegetation, location, and soil type were considered. Organic S exceeded 65 percent of total S in all but one site for both intermediate (20-40 cm; primarily A/B) and deeper (40+ cm;B,C) horizons. In almost all cases, the adsorbed sulfate anion constituted substantially less of the total S than did organic S. Carbon-bonded S was the most prevalent form of organic S for most sites at all depths. Adsorbed ester sulfate, recovered by extraction with basic phosphate, generally constituted a substantial portion of the adsorbed S pool for both O1 and O2 components of the forest floor and for the uppermost mineral horizon of most sites. This trend did not hold true with increasing depth. Because organic S was the dominant form of S, irrespective of horizon, the data suggest that organosulfur formation, not sulfate adsorption, may represent the primary mechanism for S retention in forest soil.

9. **Barr, Thomas C., Jr. 1971.** The North American *Pterostichus* of the subgenus *Cylindrocharis* Casey (Coleoptera, Carabidae). American Museum Novitates 2445. New York: American Museum of Natural History. 14 p.

Cylindrocharis Casey, a subgenus of *Pterostichus* Bonelli, includes three species: *P.* (*C.*) *rostratus* (Newman), ranging from southeastern Canada to the southern Appalachian Mountains of Tennessee and North Carolina; *P.* (*C.*) *acutipes*, new species, from central Kentucky and Tennessee to the mountains of Tennessee, North Carolina, and northeast Georgia; and *P. hypogeus*, new species, from the Nantahala and Snowbird Mountains, North Carolina. The central Kentucky populations of *acutipes* are described as a distinct subspecies, *P.* (*C.*) *a. kentuckensis.*

10. **Barrett, Jeffrey C.; Grossman, Gary D. 1988.** Effects of direct current electrofishing on the mottled sculpin. North American Journal of Fisheries Management. 8: 112-116.

The effects of electrofishing on survival were examined by filling three tanks with mottled sculpin *Cottus bairdi* collected by electrofishing (treatment) and three by kick-seining (control). All deaths were recorded for at least 30 days. Patterns of survival were not significantly different among tanks or between control versus treatment. The insignificant treatment effect suggests that electrofishing does not adversely influence short-term survival of mottled sculpin; a similar result was obtained for several other stream fishes. To test multiple electrofishing exposures, we conducted another experiment, for 5 weeks, in four artificial stream sections. Treatment mottled sculpin were shocked, and both treatment and control fish were handled weekly. Although overall survival in all stream sections was lower than that seen in the first experiment, there were no significant differences in survival among sections or between treatments, suggesting that handling stress was a greater determinant of mortality than electrofishing.

11. **Barry, P. J.; McDowell, W. E. 1970.** Evaluation of southern pine beetle on the Wayah Ranger District, Nantahala National Forest, North Carolina. Rep. 71-1-2. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry, Division of Forest Pest Control. 4 p.

An aerial photographic and ground survey of southern pine beetle, *Dendroctonus frontalis* Zimm., infestations was performed in August 1970 within the purchase boundary of the Wayah Ranger District of the Nantahala National Forest. Survey results revealed a continuing low beetle population over the 390,000-acre area. Even though a small nucleus of live beetles was found, it is unlikely that the southern pine beetle population will become a problem in this area during the remaining months of 1970.

12. **Barten, Paul K., reviewer. 1989.** Forest hydrology and ecology at Coweeta. American Scientist. 78: 64.

A review of the Coweeta Symposium volume.

13. **Benfield, E. F.; Webster, J. R. 1985.** Shredder abundance and leaf breakdown in an Appalachian Mountain stream. Freshwater Biology. 15: 113-120.

Breakdown rates of dogwood, red maple and white oak leaves were investigated at two first-order and two second-order sites in an Appalachian Mountain stream. Leaves exposed in mesh bags were sampled on eight occasions over a 207-day period and breakdown rates were

compared using an exponential decay model. There was a consistent ranking in leaf breakdown rate within each site, i.e., dogwood > red maple > white oak, and all species broke down faster at second-order than at first-order sites. Our data suggest that differences in species-specific leaf breakdown rates were largely a function of shredder abundance on the leaves.

14. **Benfield, E. F.; Webster, J. R.; Golladay, S. W.; Peters, G. T.; Stout, B. M. 1991.** Effects of forest disturbance on leaf breakdown in southern Appalachian streams. Verhandlungen Internationale Vereinlgung fur Theoretische und Angewandte Limnologie. 24: 1687-1690.

Breakdown rates of four species of forest leaves were measured in streams at Coweeta draining logged and mature forested watersheds. Leaves were selected to range from those that breakdown rapidly (dogwood) to those that are resistant (rhododendron). Breakdown rates fit an exponential model of time and were generally faster in streams draining disturbed areas. Differences may be due to greater movement and abrasive action or to higher biological activity in the streams draining logged areas.

15. **Benke, Arthur C.; Wallace, J. Bruce. 1980.** Trophic basis of production among net-spinning caddisflies in a southern Appalachian stream. Ecology. 61: 108-118.

Life histories and annual production were determined for six species of net-spinning caddisflies in a headwater stream of the Tallulah River in north Georgia. Five species in the family Hydropsychidae were univoltine, whereas the sixth, a member of the Philopotamidae, had at least two generations per year. Seventy-five percent of the annual production was concentrated in the two largest species, *Arctopsyche irrorata* and *Parapsyche cardis*. Analysis of gut contents indicated that detritus was the most important food source. However, almost 80 percent of all caddisfly production was attributed to animal food. Net-spinning caddisfly production in this mountain stream appears to be limited by the amount of high-quality food available in the seston.

16. **Berglund, Erwin R., reviewer. 1989.** Forest Hydrology and Ecology at Coweeta. Water Resources Bulletin. 25(2): 455-458.

A review of the Coweeta Symposium volume.

17. **Berish, C. W.; Ragsdale, H. L. 1985.** Chronological sequence of element concentrations in wood of *Carya* spp. in the southern Appalachian Mountains. Canadian Journal of Forest Resources. 15: 477-483.

Tree-ring analyses of hickory from reference watersheds revealed that concentrations of lead, aluminum, and zinc are increasing, that concentrations of copper, cadmium, nickel, and manganese have remained generally constant since the 1880's, and that hickory annual radial growth increments are declining. Lead, aluminum, and zinc burdens, unlike their respective concentrations, have remained generally constant during the 1900's. The interpretation of growth and burden data indicates that hickory trees are in a mature phase of their life cycle and that annual growth does not seem to be reduced by pollutants.

18. **Berish, C. W.; Ragsdale, H. L. 1986.** Metals in low-elevation, Southern Appalachian forest floor and soil. Journal of Environmental Quality. 15(2): 183-187.

Concentrations of Ca, K, Mg, Mn, Cd, Co, Cu, Pb, and Zn in Southern Appalachian soils from two 90-year-old forests were determined by three extraction methods. Total soil Ca, K, Mg, and Mn pools were two or more orders of magnitude greater than trace metal pools. Fractions of the total metal pools that were readily and potentially available generally decreased in depth. Litter and humus trace metal concentrations of two low-elevation watersheds in the Coweeta Basin contain lower concentrations of Cu, Zn, and Pb than commonly reported for the Northeastern United States. The largest trace metal pool in forest floor litter and humus was lead.

19. **Best, G. Ronnie; Monk, Carl D. 1975.** Cation flux in hardwood and white pine watersheds. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symposium Series Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 847-861. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

The nutrient content of precipitation input, throughfall, litter flow through, soil percolation, and stream discharge was measured in a hardwood and in a white pine watershed. Amounts of water passing through various levels of the forest ecosystems changed markedly from input to output, and leaching of cations from vegetation exhibited pronounced seasonal changes. Leaching of potassium, calcium, and magnesium was least during dormant winter months but increased with commencement of spring growth. Most potassium was leached from the leaves before leaf fall, but most calcium and magnesium losses occurred after leaf fall. A reduction of sodium in throughfall during the summer months was evident in white pines. Once the water became streamflow discharge, the cation load was similar to its original input level, giving evidence of the ability of the ecosystem to minimize external loss while maintaining a large internal flux.

20. **Bisweil, H. H.; Hoover, M. D. 1945.** Appalachian hardwood trees browsed by cattle. Journal of Forestry. 43: 675-676.

Cattle are selective in the tree species they browse. Percentage breakdowns by species are given for the foliage eaten by cattle on a 145-acre Appalachian watershed during 1941 and 1942. Herb utilization approached 100 percent after 1 year of grazing, and the grazing capacity of the watershed was reduced by 50 percent during 1 year of browsing.

21. **Black, Peter E. 1959.** Interception of rainfall by a hardwood canopy. University of Istanbul, Orman Fakultesi; Dergisi. 9(2): 218-224.

Results of studying rainfall intercepted by cove hardwoods growing on an old field are discussed, and equations for determining throughfall during fall, winter, spring, and summer are presented. Estimates of the number of throughfall gages required for interception studies in similar stands are given.

22. **Black, P. E.; Clark, P. M. 1958.** Timber, water, and Stamp Creek. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 12 p.

This illustrative brochure outlines the proper logging techniques used in a timber sale on the Chattahoochee National Forest, Stamp Creek, GA. A satisfactory profit was realized by the logger without serious erosion or damage to the streams and fish.

23. **Blair, John M. 1988.** Nitrogen, sulfur and phosphorus dynamics in decomposing deciduous leaf litter in the Southern Appalachians. Soil Biology and Biochemistry. 20(5): 693-701.

For 2 years, decomposition rates and N, S and P dynamics of flowering dogwood, red maple and chestnut oak litter were examined in a mixed deciduous forest. Dogwood litter decomposed the fastest, chestnut oak the slowest. First 6-month losses were highly correlated with ethanol-soluble and total soluble components. First-year annual decay rates were negatively correlated with initial percentage of lignin and lignin-to-N ratios. Second-year decay rates were significantly slower for dogwood and maple litter, but not for chestnut oak. Relative concentrations of N, S and P increased during the decomposition of each litter type. Nitrogen release began when C-to-N ratios decreased to between 25 and 34. Only dogwood litter appeared to release P by the end of the study. Dogwood litter also had a low initial C-to-S ratio and an immediate net release of S which continued throughout the study. The other litter types, which had higher initial C-to-S ratios, immobilized S throughout the study.

24. **Blair, John M. 1988.** Nutrient release from decomposing foliar litter of three tree species with special reference to calcium, magnesium and potassium dynamics. Plant and Soil. 110: 49-55.

Calcium, magnesium and potassium dynamics in decomposing litter of three tree species were measured over a 2-year period. The species studied were flowering dogwood, red maple and chestnut oak. The order of decomposition was: *C. florida* > *A. rubrum* > *Q. prinus*. Calcium concentrations increased following initial leaching losses. There were net releases of Ca from all three litters since mass loss exceeded increases in concentration. Net release of Ca by the end of 2 years was 42 percent of initial inputs in litterfall. Magnesium concentrations increased in the second year, following decreases due to leaching during the first year. Net release of Mg by the end of 2 years was 58 percent of initial inputs. Potassium concentrations decreased rapidly and continued to decline throughout the study. Net release of K by the end of two years was 91 percent of initial inputs. Similar data on N, S and P dynamics were combined to estimate the release of nutrients from litter. The relative mobility of all six elements in relation to mass loss after 2 years was: K > Mg > mass > Ca > S > P > N.

25. **Blair, John M.; Crossley, D. A., Jr. 1988.** Litter decomposition, nitrogen dynamics and litter microarthropods in a Southern Appalachian hardwood forest 8 years following clearcutting. Journal of Applied Ecology. 25: 683-698.

Litter decomposition rates, nitrogen dynamics and litter microarthropods on xeric slopes of a watershed 8 years after clearcutting (WS 7) and on an adjacent reference watershed (WS 2) at Coweeta were measured using litterbags containing *Cornus florida* L., *Acer rubrum* L. and *Quercus prinus* L. Results from this study were compared with those for earlier studies to assess the longer-term changes induced by canopy removal. Litter decomposition rates and net immobilization of nitrogen in litter substrates were reduced by clearcutting. Mean annual densities of total litter microarthropods remained 28 percent lower at 8 years after cutting on WS 7 than on WS 2. Clearcutting initially reduced mean annual densities of litter microarthropods by >50 percent. Relative abundances of major groups were altered. Mesostigmata and Oribatei densities averaged 50 and 54 percent lower than on WS 2 while Prostigmata and Collembola densities averaged 20 and 24 percent lower. Results of this study differ from those at northern hardwood forest sites where clearcutting caused increased decomposition rates.

26. **Blair, John M.; Crossley, D.A., Jr.; Callaham, Leslie C. 1991.** A litterbasket technique for measurement of nutrient dynamics in forest floors. Agriculture, Ecosystems and Environment. 34: 465-471.

This describes a litterbasket technique for quantifying decomposition and changes in litter and forest floor nutrient pools over time. Litterbaskets are constructed of wire cloth, 10x10x10 cm. Intact cores, removed from forest floors, are separated into individual strata (litter layer, F-layer, soil) with plastic window screen. The core is reassembled in the litterbasket, which is replaced in the hole from which the core was removed. Preweighed aliquots of experimental substrates can replace the litter layer. The advantages of the litterbasket method include: (1) improved microclimatic exposure relative to litter enclosed in litterbags; (2) opportunity to input exogenous radioactive or stable isotope tracers; (3) quantification of changes in nutrient contents in the various layers of the forest floor over time; (4) easy extraction of invertebrates and quantification of microbial populations from individual horizons; (5) the ability to quantify the movement of radioactive or stable tracers from litter through the forest floor profile over time.

27. **Blair, John M.; Crossley, D. A., Jr.; Rider, Steve. 1989.** Effects of naphthalene on microbial activity and nitrogen pools in soil-litter microcosms. Soil Biology and Biochemistry. 21(4): 507-510.

Results suggest that naphthalene may directly affect microbial populations and activity and alter nitrogen dynamics and that caution should be used in interpreting results of field studies using naphthalene to exclude microarthropods. Naphthalene was applied three times during a 56-day study of microbial respiration, numbers of bacteria and fungi, and litter and soil nitrogen pools in litter-soil microcosms containing microbes but no mesofauna. Total respiration was unaffected by the first application of naphthalene, but increased upon subsequent applications. Bacteria and fungi in the litter and soil were quantified separately. Numbers of bacteria were significantly higher in both litter and soil of naphthalene-treated microcosms. Lengths of total and FDA-active fungal hyphae in the litter and soil, respectively, were significantly lower in the naphthalene treatment. Mass loss of litter was not affected. Both the final concentration and absolute amount of N in the litter were reduced by naphthalene, as was soil extractable NH_4-N and NO_3- plus NO_2-N.

28. **Blair, John M.; Parmelee, Robert W.; Beare, Michael H. 1990.** Decay rates, nitrogen fluxes, and decomposer communities of single- and mixed-species foliar litter. Ecology. 71(5): 1976-1985.

Decomposition rates, N fluxes, and abundances of decomposer organisms were quantified in mixed-species litterbags (containing leaves of *Acer rubrum*, *Cornus florida*, and *Quercus prinus*) and in single species litterbags. Single-species litterbags were used to generate predicted decay rates, N fluxes, and abundances of decomposer organisms for mixed-species litterbags. Observed values from mixed bags were compared with predicted to determine if interaction effects occurred. Decay rates of mixed species litterbags during the 1-year study were not significantly different than predicted from decay rates of individual component species. However, there were significant interaction effects on N fluxes and abundances of decomposer organisms. For example, estimates of ecosystem-level N fluxes, based on data from single-species litterbags, resulted in a 64 percent underestimate of N released by day 75 and a 183 percent overestimate of N accumulated in the litter by day 375. The deviation of observed N fluxes from predicted may be the result of differences in the decomposer community.

29. **Blood, Elizabeth R.; Swank, Wayne T.; Williams, Thomas. 1989.** Precipitation, throughfall, and stemflow chemistry in a coastal loblolly pine stand. In: Sharitz, Rebecca R.; Gibbons, J. Whitfield, eds. Freshwater wetlands and wildlife: DOE Symp. Ser. 61 (CONF-8603101); 1986 March 24-27; Charleston, SC. Oak Ridge, TN: U.S. Department of Energy, Office of Scientific and Technical Information: 61-78.

Precipitation, throughfall, and stemflow quantities and chemistry were characterized in a 20-year-old loblolly pine stand at North Inlet, South Carolina, over a 20-month period. Throughfall and stemflow water fluxes were 73 and 8 percent of 178 cm rainfall; canopy loss was 19 percent. Site precipitation chemistry is strongly influenced by prevailing winds from the ocean or nearby industries. High concentrations of Na and Cl were associated with winter and spring frontal storms and SO_4 with summer thunderstorms. Sulfate, Cl, Na, K, Ca, and Mg enriched water passing through the canopy. At least 26 percent of the cation leaching in throughfall can be accounted for by hydrogen exchange with the canopy. Nitrate-nitrite, NH_4, and total nitrogen were depleted in throughfall while PO_4 and total P fluxes were unchanged. Stemflow was significant in delivery of nutrients to the forest floor and accounted for 13 to 20 percent of the total flux for all constituents except NO_3-NO_2 and total P (4 and 8 percent). Temporal patterns of nutrient fluxes suggest dry deposition is an important process of nutrient input to the ecosystem.

30. **Boring, Lindsay R.; Monk, Carl D.; Swank, Wayne T. 1981.** Early regeneration of a clear-cut Southern Appalachian forest. Ecology. 62: 1244-1253.

Hardwood forest regeneration was assessed on a Southern Appalachian watershed during the first year following clearcutting. First-year net primary production (NPP) on the clearcut was 22 percent of that of a nearby undisturbed hardwood forest. First-year nutrient pools in NPP for N, P, K, Mg, and Ca were estimated at 29 to 44 percent of those in the NPP of the control. The greatest NPP and nutrient pools were represented in descending order by hardwood sprouts, herbs, vines, and seedlings. The woody successional species had higher concentrations of N and P than most other woody species. Herbs as a group had significantly higher foliar concentrations of K than woody species. Woody successional and herbaceous species had higher biomass and elemental pools than other woody species. Following forest disturbance, these fast-growing species conserve substantial pools of nutrients in their biomass and initiate a rapid recovery of forest elemental cycling processes.

31. **Boring, Lindsay R.; Swank, Wayne T. 1984.** Symbiotic nitrogen fixation in regenerating black locust (*Robinia pseudo-acacia* L.) stands. Forest Science. 30(2): 528-537.

Black locust is a dominant early successional tree in the Southern Appalachians that symbiotically fixes N, grows rapidly, and has a relatively short life span. Objectives of this research were to study seasonal patterns of nodule biomass and N-fixation activity in 4-year-old black locust stands over the span of 1 year, and to determine the importance of symbiotic N fixation as an input to a regenerating forest.

32. **Boring, L.R.; Swank, W.T. 1984.** The role of black locust (*Robinia pseudo-acacia*) in forest succession. Journal of Ecology. 72: 749-766.

Early forest regeneration in Southern Appalachian hardwood forests is dominated by the woody

nitrogen-fixing legume, black locust. It is most prevalent on clear-felled areas, abandoned pastures, disturbed roadsides, and historically may have been an important colonizer of burned sites. It commonly reproduces from seed, but sprouting from stumps and roots is the most prevalent means of regeneration with rapid early growth, attaining heights up to 8 m in 3 years. Except for stands on high-nutrient sites, growth decreases after 10 to 20 years. In less vigorous stands, stem mortality may be high due to attacks by the locust stem borer. The high mortality of black locust is an early successional mechanism that releases codominant species such as *Liriodendron*, and creates canopy gaps favorable for growth of longer-lived individuals. Patterns of N accretion are similar to those for other woody nitrogen-fixing species with peak N fixation occurring in early to intermediate stages of forest succession, and declining with later successional development.

33. **Boring, Lindsay R.; Swank, Wayne T. 1986.** Hardwood biomass and net primary production following clearcutting in the Coweeta Basin. In: Brooks, Robert T., Jr., ed. Proceedings of the 1986 southern forest biomass workshop; 1986 June 16-19; Knoxville, TN. Norris, TN: Tennessee Valley Authority: 43-50.

A watershed at the Coweeta Hydrologic Laboratory was clearcut in 1977 as part of an interdisciplinary study of the physical, chemical and biological effects of logging by cable-yarding upon both terrestrial and aquatic components of the hardwood forest ecosystem. This paper compares species composition, leaf area index, biomass, and net primary production across sites and over the first 8 years of regrowth with values for an adjacent, uneven-aged, mixed hardwood forest. Vegetation influences upon nutrient cycling processes are briefly discussed.

34. **Boring, L. R.; Swank, W. T.; Monk, C. D. 1988.** Dynamics of early successional forest structure and processes in the Coweeta basin. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 161-179.

A hardwood forested watershed at Coweeta was clearcut as part of an interdisciplinary study of the physical, chemical, and biological effects on both terrestrial and aquatic components of the ecosystem. Specific objectives were: (1) to examine differences in forest regeneration trends among former cove, chestnut oak, and xeric scarlet oak-pine sites; (2) to compare species composition, leaf area index, biomass, net primary production, nutrient uptake, and nutrient accretion over the first 3 years of regeneration with values for an adjacent, uneven-aged, mixed hardwood forest; and (3) to relate regeneration of forest structure to fundamental ecosystem processes of nutrient uptake, immobilization, and transfers.

35. **Boring, Lindsay R.; Swank, Wayne T.; Waide, Jack B.; Henderson, Gray S. 1988.** Sources, fates, and impacts of nitrogen inputs to terrestrial ecosystems: review and synthesis. Biogeochemistry. 6: 119-159.

Rates of both symbiotic and nonsymbiotic nitrogen fixation appear greater during early successional stages of forest development and have major impacts on nitrogen dynamics and ecosystem productivity. Fates and impacts of these nitrogen inputs are important but inadequately understood. The relative importance of nitrogen inputs from atmospheric deposition and biological fixation is reviewed for nonagricultural terrestrial ecosystems. Bulk precipitation inputs of N are the same order of magnitude or larger than the inputs from nonsymbiotic fixation, especially in areas influenced by industrial activity. Bulk precipitation measurements may underestimate total atmospheric deposition by 30 to 40 percent because they generally do not include all forms of wet and dry deposition. Symbiotic fixation generally ranges from 10 to 160 kg N/ha/yr in ecosystems where N-fixing species are present during early successional stages. These input processes are highly variable in space and time. Specific needs for comparative information on both nitrogen deposition and fixation are suggested.

36. **Bosch, J.M.; Hewlett, J.D. 1982.** A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology. 55: 3-23.

This summary and review of 94 catchment experiments shows that accumulated information on the effect of vegetation changes on water yield can be used for practical purposes. The directions of change in water yield following forest operations can be predicted with fair accuracy since no experiments, with the exception of perhaps one, have resulted in reductions in water yield with reduction in cover, or increases in yield, with increases in cover. The approximate magnitude of changes can also be estimated. Pine and eucalypt forest types cause on average 40-mm change in water yield per 10-percent change in cover and deciduous hardwood and scrub ~25 and 10 mm, respectively. Maximum changes of 660 mm were experienced at Coweeta, North Carolina. An assimilation of the collective experimental results shows that more careful design and expansion of experiments to certain rainfall regions would augment statistical inference.

37. **Boyer, J. S.; Knipling, E. B. 1965.** Isopiestic technique for measuring leaf water potentials with a thermocouple psychrometer. Proceedings of the National Academy of Science. 54(4): 1044-1051.

This new technique for determining rate of vapor flux between thermocouple and leaf is free of error caused by leaf resistance. The method can be used to measure leaf resistance directly and gives more accurate measurements of water potential than do other methods.

38. **Brannan, James R.; Reneke, James A.; Waide, Jack. 1984.** A diffusion model of forest succession. Mathematical Biosciences. 69: 131-149.

Based on a tree by tree replacement mechanism, a diffusion model of forest stand canopy composition is formulated and analyzed. The model is used to explore composition dichotomies by estimating coefficients from

forest stand data and interpreting the results in terms of mechanisms for succession. The model yields a concrete characterization of the succession phenomenon known as the climax state.

39. **Brater, E. F. 1939.** The unit hydrograph principle applied to small watersheds. Proceedings of the American Society of Civil Engineers. 65: 1191-1215.

Tests of the applicability of the unit hydrograph principle on 22 small watersheds ranging from 4 to 1877 acres led the author to conclude that this method is one of the best practical devices for predicting floodflows.

40. **Britton, K.O. 1993.** Anthracnose infection of dogwood seedlings exposed to natural inoculum in western North Carolina. Plant Disease. 77(1): 34-37.

Groups of 25 healthy dogwood seedlings were exposed for 2 weeks to naturally occurring inoculum under mature, diseased trees at 2-week intervals for three growing seasons. After exposure, seedlings were placed in an incubation room and supplied with trickle irrigation and flourescent lighting. Following incubation, percentage of leaf area infected (LAI) was estimated visually. In 1989, consistent rainfall throughout the summer created conditions conducive to infection and LAI ranged from 11 to 47 percent. In 1990 and 1991, LAI was less than 5 percent until heavy infection began in mid-May. Midsummer droughts reduced LAI to less than 5 percent. LAI increased with renewed rainfall. Numerous secondary infection cycles occurred. Regression analysis showed that 34 percent of the variance in LAI was explained by 2-week rainfall totals and 17 percent by the LAI of the previous seedling group. This supports the hypothesis that secondary infection cycles in southwestern North Carolina depend on consistently recurring rainfall and inoculum buildup.

41. **Brockman, Ellis R.; Todd, Robert L. 1974.** Fruiting myxobacters as viewed with a scanning electron microscope. International Journal of Systematic Bacteriology. 24: 118-124.

Unfixed fruiting bodies of myxobacters have been viewed in great detail with a scanning electron microscope. Specimens of species of the genera *Myxococcus*, *Chondrococcus*, *Archangium*, *Stelangium*, *Melittangium*, *Cystobacter*, *Polyangium*, *Stigmatella*, and *Chondromyes* were examined. The desirability of using the scanning electron microscope for the study of the gross morphology of myxobacter structures has been clearly demonstrated.

42. **Bruce, Richard C. 1988.** Life history variation in the salamander *Desmognathus quadramaculatus*. Herpetologica. 44(2): 218-227.

Age at metamorphosis and at first reproduction were studied in three populations of *Desmognathus quadramaculatus* in the southern Blue Ridge Mountains of southwestern North Carolina. Four age classes of larvae were identified in all three populations through the analysis of size distributions. The frequency of early metamorphosis at 2 or 3 years varied considerably among the populations. This variation was reflected in the size distributions of both larvae and postmetamorphic juveniles. The minimum age at first reproduction was estimated to be 6 years in males and 7 years in females in all three populations. Age at metamorphosis and age at first reproduction probably vary independently in *D. quadramaculatus*. It appears that interspecific variation in adult body size in the genus *Desmognathus* is correlated positively with age at first reproduction and may not reflect variation in growth rates.

43. **Bruce, Richard C.; Hairston, Nelson G., Sr. 1990.** Life-history correlates of body-size differences between two populations of the salamander, *Desmognathus monticola*. Journal of Herpetology. 24(2): 124-134.

Samples were compared of *Desmognathus monticola* taken independently at two nearby localities in southwestern North Carolina. Larger adult body sizes are attained by both sexes at Coweeta Hydrologic Laboratory in the Nantahala Mountains than at Wolf Creek in the Cowee Mountains. The juvenile period appears to be longer in the former population, resulting in larger sizes at maturation in both males and females. The proportion of older males is greater at Coweeta than at Wolf Creek, suggesting higher male survival in the former population. Clutch sizes are lower at Coweeta than at Wolf Creek, even though Coweeta females are larger. This suggests that the population differences in body size may represent differences in age at maturation rather than differences in growth rates. The pattern of variation in life history parameters suggests that extrinsic survival probabilities differ between the sites, with Coweeta representing a safer environment for *D. monticola* than Wolf Creek.

44. **Burgess, Robert L.; Swank, Wayne T. 1972.** Analysis of ecosystems in the Eastern Deciduous Forest Biome - U.S. International Biological Program. In: Proceedings of the 7th World Forestry Congress; 1972 October 3-14; Buenos Aires, Argentina. Buenos Aires, Argentina: Librart, Department of Argentine Scientific Publications: 4920-4924.

The organization and research structures of the Eastern Deciduous Forest Biome are outlined, with emphasis on the major research sites.

45. **Burnash, Robert J. C., reviewer. 1988.** Forest hydrology and ecology at Coweeta, Ecological Studies Volume 66. Bulletin of the American Meteorological Society. 69(11): 1357-1358.

A review of the Coweeta Symposium volume.

46. **Burt, T. P., reviewer. 1989.** Forest hydrology and ecology at Coweeta. Hydrological Processes. 3: 289-293.

A review of the Coweeta Symposium volume.

47. **Burt, T.P.; Swank, W.T. 1992.** Flow frequency responses to hardwood-to-grass conversion and subsequent succession. Hydrological Processes. 6(2): 179-188.

A 8-9 ha (22 acre) catchment at the Coweeta Hydrologic Laboratory in western North Carolina was cleared of hardwood forest in 1958 and 1959 and seeded to Kentucky 31 fescue grass in 1959 and 1960. Grass production was high in years when fertilizer was applied and water yield was very similar to that expected from the original forest cover. As grass production declined, so water yields rose, with important increases in the magnitude of both low-frequency flows and, particularly, in baseflow. In 1967 and 1968, when all vegetation was deadened in the catchment, the discharge levels in all flow-frequency classes were higher. Natural revegetation was then allowed and water yields gradually declined towards the expected level, although there remained a tendency for winter flows to remain higher, and for summer flows to be lower than expected. This paper updates the earlier work of Hibbert (1969) and uses flow-duration curves to extend his results.

48. **Bush, P. B.; Neary, D. G.; Dowd, J. F.; Allison, D. C.; Nutter, W. L. 1986.** Role of models in environmental impact assessment. Proceedings of Southern Weed Science Society. 39: 502-516.

The models CREAMS and PRZM were used to simulate pesticide movement from forested watersheds in the Upper Piedmont and the lower Appalachian Mountains. Comparison of simulations with measured hexazinone loss from a treated watershed in the Upper Piedmont showed that CREAMS accurately predicted hexazinone concentrations for storm events up to 75 days after application. For storm events occurring between 75 and 270 days after application, CREAMS underpredicted storm hexazinone concentrations. Comparison of PRZM simulations with measured picloram movement in a treated, forested Southern Appalachian watershed showed that PRZM accurately predicted subsurface picloram movement when site-modified runoff curve number, partition coefficient, and half-life were employed.

49. **Cataneo, Robert. 1969.** A method for estimating rainfall rate-radar reflectivity relationships. Journal of Applied Meteorology. 8(5): 815-819.

Raindrop-size distributions obtained with the drop camera have been used to determine rainfall rate-radar reflectivity relationships for nine different locations throughout the world. Since the climates sampled were quite varied, an extrapolation of the Z-R relationships to other areas of the world with similar "drop-spectra climates" can be performed. Two climatic parameters, the mean annual percent of rain days that are thunderstorm days, and the mean annual relative humidity at 0.5 km above ground, were found to be highly correlated with the coefficient A and exponent b in the Z-R equation. Regression equations based on the two climatic parameters were determined, permitting an estimation of the Z-R relationship for any area once the parameters are obtained.

50. **Cataneo, Robert; Stout, Glenn. 1968.** Raindrop-size distributions in humid continental climates, and associated rainfall rate-radar reflectivity relationships. Journal of Applied Meteorology. 7(5): 901-907.

Raindrop-size spectra obtained with the raindrop camera have been analyzed from two locations, Island Beach, NJ, and Franklin, NC. The spectra were analyzed with respect to total number of drops per average rain rate per cubic meter of sample, geometric mean diameter, mode diameter, and the diameter of drops at which half the liquid water content lies above that diameter and half below. The results indicate that the distributions from both locations are quite similar. Rainfall rate-radar reflectivity relationships indicate that cold frontal rains, upslope rains, and tropical storm rains generally have smaller drops.

51. **Cataneo, Robert; Vercellino, David L. 1972.** Estimating rainfall rate-radar reflectivity relationships for individual storms. Journal of Applied Meteorology. 2(1): 211-213.

In order to improve the accuracy with which radar estimates rainfall rates and amounts, a method has been developed whereby the rainfall rate-radar reflectivity relationships may be estimated for approaching precipitation. The estimating equation is based on atmospheric parameters which may be obtained in advance of precipitation, from standard radiosonde data. Comparisons are made between the present model and other methods concerning their effectiveness in determining appropriate rainfall rate-radar reflectivity relationships.

52. **Chellemi, Dan O.; Britton, Kerry O. 1992.** Influence of canopy microclimate on incidence and severity of dogwood anthracnose. Canadian Journal of Botany. 70: 1093-1096.

Incidence and severity of dogwood anthracnose within the interior and exterior canopies of exposed and understory dogwood trees were recorded over a 53-day period during the summer of 1990. Concurrent measurements of vapor pressure deficit, air temperature, evaporative potential, and photosynthetically active radiation within the canopies were also recorded. Disease severity was significantly different among all canopy locations, with the lowest severity in exterior canopies of exposed trees and the greatest severity in canopies of understory trees. Of the climatic variables measured, evaporative potential provided the most consistent contrast among microclimates at the various canopy locations. Disease incidence and severity were greater in canopies associated with low levels of evaporative potential.

53. **Chellemi, D. O.; Britton, K. O.; Swank, W. T. 1992.** Influence of site factors on dogwood anthracnose in the Nantahala Mountain Range of Western North Carolina. Plant Disease. 76(9): 915-918.

Sixty-five 0.08-ha plots located within the Nantahala Mountain range of western North Carolina were surveyed for dogwood anthracnose, caused by *Discula destructiva*. The incidence of disease and disease severity (extent of foliar symptoms and limb dieback) within canopies of *Cornus florida* was determined for all trees with a diameter

of 1.0 cm or greater at 1.37 m above ground. The incidence of dogwood anthracnose ranged from 53 to 100 percent; the severity of foliar symptoms, from 3 to 65 percent; and limb dieback, from 8 to 65 percent. Plots were inventoried, and the relationship between dogwood anthracnose and 14 variables representing indices of host density, expressed in stems per ha or importance value, respectively, and azimuth accounted for a significant portion of explainable variation in dogwood anthracnose. Anthracnose was inversely related to absolute or relative measurements of host density. Disease was greatest in northeast-facing plots and lowest in southwest-facing plots. Elevation had a minor influence on disease incidence and limb dieback. Geographic features, as described by the landform index, had a minor influence on disease incidence.

54. **Clapp, Cecil E. 1956.** Regulating streamflow from small watersheds. The Forest Farmer. (16)2: 18-19.

An introduction to some principles of watershed management based on Coweeta research.

55. **Clinton, B.D.; Boring, L.R.; Swank, W.T. 1993.** Characteristics of canopy gaps and drought influences in oak forests of the Coweeta Basin. Ecology. 74(5): 1551-1558.

Canopy gaps in Southern Appalachian mixed-*Quercus* forests were characterized to assess the impact of the 1985-88 record drought on patterns of tree mortality. Among 1 to 5-year old gaps, the most common gap type was the 1-year-old single tree snag, accounting for 49 percent of all gaps sampled; 65 percent of all gaps occurred within 2 years of the drought peak. Gap area ranged from 40 to 850 m^2, averaged 239 m^2, with a median of 152 m^2. Rates of gap formation were 0.8 gaps/ha^{-1}/yr^{-1} affecting 2.0 percent of the area in the *Quercus* forest type in 1988. The most frequent gap-forming species were red oaks. Evidence suggests that moisture stress brought on by severe drought increases the susceptibility of *Quercus* species to the shoestring fungus *Armillaria mellea*.

56. **Clinton, B.D.; Vose, J.M.; Swank, W.T. 1993.** Site preparation burning to improve southern Appalachian pine-hardwood stands: vegetation composition and diversity of 13-year-old stands. Canadian Journal of Forest Research. 23: 2271-2277.

Stand conversion through cutting and burning, and planting of *Pinus strobus* L., in low-quality, mixed pine/hardwood ecosystems containing a *Kalmia latifolia* L. dominated understory, is a common prescription on xeric Southern Appalachian forest sites. Four 13-year-old stands were examined for the effects of this treatment on early vegetation composition and diversity. Two of these stands were mechanically released at age 6. Density and basal area were estimated for understory and overstory components and density and percent cover for the herb component. Species diversity (Shannon-Wiener Index) was estimated, and comparisons were made between layers, sites, and treatments (release vs. nonrelease). Diversity estimates were 3.19, 1.74, and 2.45 for the herb, shrub, and overstory layers, respectively, across all sites and treatments. For perspective, comparisons were made with a reference stand typical of stands receiving site preparation burning in the Southern Appalachians. Overstory and herb diversity estimates were significantly lower for the reference stand compared to the same layers in the 13-year-old stands.

57. **Coleman, D.C.; Odum, E.P.; Crossley, D.A., Jr. 1992.** Soil biology, soil ecology, and global change. Biology and Fertility of Soils. 14: 104-111.

This overview paper addresses aspects of scaling in space and time, and scaling in relation to micro-and-macro habitats. Ecological processes in soils are examined for possible generalizations about processes and organisms, across a wide range of different habitats. Problems of scaling in space and time that have an important impact on processes associated with global change are outlined.

58. **Cornaby, B. W.; Gist, C. S.; Crossley, D. A., Jr. 1975.** Resource partitioning in leaf-litter faunas from hardwood and hardwood-converted-to-pine forests. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symp. Ser. Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 588-597. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

The structure and function of litter faunas were measured from the forest floors of two forest watersheds; mature hardwood (reference) and adjacent white pine, once hardwood (experimental) forests. The biomass of some 18 combined taxa of litter animals was about one-third lower, numerical abundances were about one-half lower, and standing crops of calcium and potassium were also lower in the pine plantation than in the hardwood system. These data were synthesized as models of the cryptozoans' food webs. In the hardwood watershed, 11 percent of the calcium and 3 percent of the potassium from annual leaf-litter input were processed by the litter animals. By contrast, 2 percent of the calcium and 28 percent of the potassium from annual litter input entered the food webs of the litter fauna in the white pine watershed.

59. **Cornaby, Barney, W.; Waide, Jack B. 1973.** Nitrogen fixation in decaying chestnut logs. Plant and Soil. 39: 445-448.

Nitrogen fixation is shown to occur in decaying logs of American chestnut, *Castanea dentata* (Marsh.) Borkh., by acetylene reduction techniques, and its significance is considered in relation to log decomposition in forest ecosystems.

60. **Cosby, B.J.; Hornberger, G.M. 1990.** Calibration/validation of MAGIC for Coweeta watersheds. Corvallis, OR: U.S. Environmental Protection Agency; completion report; project AR51-015-C29. 232 p.

The purpose of project AR51-015-C29 is to calibrate and validate MAGIC (Model of Acidification of Groundwater In Catchments) for Coweeta Watersheds 34 and 36. The intent is to demonstrate that MAGIC is capable of simulating surface chemistry at sites where high-frequency data are available. The results will be used to evaluate the application of MAGIC to NSS stream sites in the Southern Blue Ridge and in the mid-Appalachian region.

61. **Costa, J.T., III; Crossley, D.A., Jr. 1991.** Diel patterns of canopy arthropods associated with three tree species. Environmental Entomology. 20(6): 1542-1548.

Canopy arthropods on dogwood, red maple, and yellow poplar were bag-sampled during the day and night on six dates from July through September on Coweeta WS7. Numbers of canopy arthropod taxa were similar both between and within tree species, as was relative taxon abundance. However, there were substantial differences in faunal composition and weighted arthropod numbers between daytime and nighttime canopies. These data suggest that canopy foliage may support greater densities and kinds of arthropods than those previously reported based on daytime sampling only. Experimental designs that include diel sampling would provide a more complete assessment of the structure and composition of canopy communities.

62. **Coulson, Robert N.; Crossley, D. A., Jr.; Gist, Clayton, S. 1971.** Patterns of Coleoptera species diversity in contrasting white pine and coppice canopy communities. American Midland Naturalist. 86: 145-151.

The information-theory index H(s) and the index D were used to measure the pattern of diversity of Coleoptera species in coppice hardwoods and white pine canopy communities. The distribution of individuals within species was measured by using redundancy and evenness indices. Diversity in the coppice was greater than in the white pine. The coppice canopy community followed a seasonal trend in diversity, evenness, and redundancy. Diversity in the white pine community did not follow an apparent seasonal trend. Considerably fewer species and individuals occurred in the white pine, which tended to magnify the importance of the appearance and disappearance of dominant species and thereby to obliterate any seasonal trend in diversity, redundancy, and evenness.

63. **Coulson, R. N.; Franklin, R. T.; Crossley, D. A., Jr. 1970.** A self-maintaining window trap for collecting flying insects. Entomological News. 81: 164.

An automatic drain system and the use of a preservative that is lighter than water are discussed as modifications of window flight traps.

64. **Courtney, Gregory W. 1994.** Biosystematics of the Nymphomyiidae (Insecta:Diptera): life history, morphology, and phylogenetic relationships. Smithsonian contributions to zoology. 550. Washington, DC: Smithsonian Institution Press. 41 p.

The family Nymphomyiidae was redescribed using additional larval, pupal and adult characteristics. The revised family includes seven species, two of which are new. *Nymphomyia dolichopeza* is widespread and locally abundant in streams of the Southern Blue Ridge Mountains, primarily in North Carolina and Georgia. World species of *Nymphomyia* are divided into two groups: (1) *alba* group (*alba*, *levanidovae*, and *rohdendorfi*; and (2) *walkeri* group (*walkeri*, *dolichopeza*, *brundini*, and *holoptica*). Keys to each life stage are provided.

65. **Craddock, G. W.; Hursh, C. R. 1949.** Watersheds and how to care for them. In: Trees, yearbook of agriculture. Washington, DC: U.S. Department of Agriculture: 603-609.

Hydrologic principles related to forest land-use as well as forest protection and management practices which influence the amount, quality, and timing of flow from forest land are discussed.

66. **Crocker, M. Tad; Meyer, Judy L. 1987.** Interstitial dissolved organic carbon in sediments of a Southern Appalachian headwater stream. Journal of the North American Benthological Society. 6(3): 159-167.

This study compared seasonal and spatial patterns of dissolved organic carbon (DOC) and interstitial DOC (IDOC) concentrations at a headwater spring seep, and explored interactions between sediment organic matter content, benthic bacterial biomass, water column DOC concentration, and sediment IDOC concentration and composition. Sediment organic matter content, IDOC concentration, water column DOC concentration, and benthic bacterial biomass were measured in a spring seep at Coweeta for 2 years. Organic matter content was increased or decreased in experimental sediments, and results measured within 3 weeks after sediment manipulation and again after 5.5 months. Benthic organic matter is a source of IDOC. The concentration of IDOC depends on sediment organic matter content, the relative proportion of high and low molecular weight IDOC compounds, and the exchange of interstitial and water column DOC.

67. **Croft, A. R.; Hoover, M. D. 1951.** The relation of forests to our water supply. Journal of Forestry. 49: 245-249.

The authors use research findings to show how forest management practices affect the quality, quantity, and timing of water yield and discuss practical implications of forest management on the solution of water problems.

68. **Cromack, Kermit, Jr.; Monk, Carl D. 1975.** Litter production, decomposition, and nutrient cycling in a mixed hardwood watershed and a white pine watershed. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symp. Ser. Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 609-624. [Available from National Technical

Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Litter production and decomposition data were obtained for a mixed-hardwood watershed and for a white pine watershed. Litterfall data were obtained for leaves, stems, flowers, acorns, and miscellaneous debris in the hardwood watershed and for needles, stems, and cones in the white pine watershed. Litterfall data obtained included biomass of litter; nitrogen, phosphorus, potassium, calcium, and magnesium contents in litter; and structural organic constituents of leaf litter. Litter decomposition data were obtained for weight loss rate and for loss rates of nutrients. Litter decomposition rates of chestnut oak, white oak, white pine, red maple, and dogwood were significantly correlated with senescent leaf carbon-to-nitrogen ratio and sclerophyll index, the sclerophyll index giving a better statistical estimate of decomposition rate.

69. **Cromack, Kermit, Jr.; Sollins, Phillip; Graustein, William C.; Speidel, Karen; Todd, Allen W.; Spycher, Gody; Li, Ching Y.; Todd, Robert L. 1979.** Calcium oxalate accumulation and soil weathering in mats of hypogeous fungus *Hysterangium crassum*. Soil Biology and Biochemistry. 11: 463-468.

Fungal mats of *Hysterangium crassum* Fischer occupied a mean of 9.6 percent of the upper 10 cm of soil developed under a 40- to 65-year-old stand of Douglas-fir in Oregon. This hypogeous basidiomycete exudes large amounts of oxalic acid, some of which precipitates with Ca in microscopic crystals of calcium oxalate. Soil oxalate concentration was significantly greater within fungal mats, and soil pH was significantly lower than in soil adjacent to mats. The quantity of Ca present as CaC_2O_4 is 0.5 the amount of exchangeable Ca in the soil and exceeds the mass of Ca lost annually in runoff.

70. **Cromack, K., Jr.; Sollins, P.; Todd, R. L.; Crossley, D. A., Jr.; Fender, W. M.; Fogel, R.; Todd, A. W. 1977.** Soil microorganism - arthropod interactions: fungi as major calcium and sodium sources. In: Mattson, W. J., ed. The role of arthropods in forest ecosystems. New York; Heidelberg; Berlin: Springer-Verlag: 78-84.

The objective of this paper is to present evidence that terrestrial fungi may be important sources of Ca and Na for saprophagous arthropods and other soil animals. Calcium, but not Na, has been reported as essential for many fungi; both elements are essential for animals.

71. **Cromack, K., Jr.; Sollins, P.; Todd, R. L.; Fogel, R.; Todd, A. W.; Fender, W. M.; Crossley, M. E.; Crossley, D. A., Jr. 1977.** The role of oxalic acid and bicarbonate in calcium cycling by fungi and bacteria: some possible implications for soil animals. In: Lohm, U.; Persson, T., eds. Soil organisms as components of ecosystems: Proceedings of the 6th international soil zoology colloquium; 1976 June 21-25; Uppsala, Sweden. Ecol. Bull. 25. Uppsala, Sweden: Swedish Soil Science Society: 246-252.

Fungi can accumulate Ca in excess of their apparent physiological needs by release of oxalic acid to form the sparingly soluble Ca oxalate. Fungal release of oxalic acid may also form stable complexes with other metallic cations, which would influence both soil weathering processes and release of P from Fe and Al hydroxyphosphates. Bacteria and *Streptomyces sp.* can decompose Ca oxalate, which recycles the cation and permits formation of calcium bicarbonates or carbonates. Oxalate decomposing bacteria and actinomycetes were isolated from the digestive systems of oribatid mites, earthworms, a springtail and two immature aquatic detritivores, a mayfly and a stonefly. A proposed Ca cycle, operative by fungi, bacteria, and soil animals in the context of the soil ecosystem, is presented.

72. **Cromack, Kermit, Jr.; Todd, Robert L.; Monk, Carl D. 1975.** Patterns of basidiomycete nutrient accumulation in conifer and deciduous forest litter. Soil Biology and Biochemistry 7: 265-268.

Nutrient data were obtained for basidiomycete sporocarps, rhizomorphs, and forest floor leaf litter samples collected from a white pine (*Pinus strobus* L.) watershed and from a mixed hardwood watershed. Basidiocarps taken from the surface litter of both watersheds were fleshy representatives of Agaricacae, Cantharellaceae or Clavariaceae. Forest floor basidiocarp samples (cap + stalk) from both watersheds had significantly greater concentrations of Cu, K, Na, P, and Zn than the leaf litter from which they were removed. Bulked rhizomorph samples from both watersheds contained significantly more Ca, K, Na, and Sr than forest floor leaf litter. Polyporaceae growing on hardwood branches concentrated Al, Mo, P, and Zn.

73. **Crossley, D. A., Jr. 1977.** The roles of terrestrial saprophagous arthropods in forest soils: current status of concepts. In: Mattson, W. J., ed. The role of arthropods in forest ecosystems. New York: Springer-Verlag: 49-56.

Soil arthropods are envisioned as accelerating (or delaying) nutrient release from decomposing organic matter. They may do this directly: by feeding upon organic matter and associated microflora; or indirectly: by channeling and mixing of the soil, improving substrate quality for microflora, inoculation of organic debris with microbes, selective grazing upon microflora, and preventing senescence of microfloral populations. It will be noted that these effects are largely anecdotal because most are difficult to quantify in a satisfactory or meaningful way.

74. **Crossley, D. A., Jr.; Callahan, J. T.; Gist, S. C.; Maudsley, J. R.; Waide, J. B. 1976.** Compartmentalization of arthropod communities in forest canopies at Coweeta. Journal of the Georgia Entomological Society. 11: 44-49.

A compartment model is described for arraying arthropod biomasses of forest canopies into functional groups. Model inputs and outputs represent linkages to other processes within the watershed ecosystem. The compartment model is evaluated for its ability to contain standing crop and biomass information, using data obtained from sampling

seems to be quite important in inhibition of regeneration of some canopy species. Individual species appear to be distributed along complex moisture gradients.

98. **Deshefy, G. Scott. 1979.** Predator escape behavior by fall cankerworm larvae, *Alsophila pometaria* (Lepidoptera: Geometridae). Entomological News. 90: 145-146.

Silk emission and dropping behavior in larvae of the fall cankerworm, *Alsophila pometaria*, enable the species to escape predation and ultimately reestablish contact with its tree host.

99. **Dighton, John; Coleman, David C. 1992.** Phosphorus relations of roots and mycorrhizas on *Rhodendron maximum* L. in the southern Appalachians, North Carolina. Mycorrhiza. 1: 175-184.

The mycorrhizal associations of *Rhododendron maximum* in the Southern Appalachian Mountains were studied in relation to the supply and demand of phosphate at three altitudes. A variety of mycorrhizal associations are described together with the ability of the differing mycorrhizal types to produce phosphatase enzyme, which was inversely related to the availability of inorganic phosphate determined by a root bioassay, as Ectomycorrhizal associations were shown to have a higher phosphatase production potential than other mycorrhizas. The availability of inorganic phosphate at different altitudes is related to turnover of organic matter and fixation capacity of the mineral soil. It is speculated that the ability of *R. maximum* to associate with a range of mycorrhizal associates is likely to improve species' fitness and enhance its competitive ability.

100. **Dils, R. E. 1953.** Influence of forest cutting and mountain farming on some vegetation, surface soil and surface runoff characteristics. Stn. Pap. 24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 55 p.

Infiltration rates, organic matter content, density, and porosity of soils were all adversely affected by conversion of a forested watershed at Coweeta to a mountain farm. Storm runoff volumes, peak discharge rates, flood peak frequencies, and overland flow were all increased. Mountain farming shortly proved to be uneconomical.

101. **Dils, R. E. 1957.** A guide to the Coweeta Hydrologic Laboratory. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 40 p.

This report replaced the 1948 guidebook and summarizes the many watershed studies at Coweeta. The research site and its water resources are described, and research methods are outlined.

102. **Dissmeyer, George E.; Corbett, E. S.; Swank, W. T. 1975.** Summary of municipal watershed management surveys in the Eastern United States. In: Proceedings, municipal watershed management symposium; 1973. Gen. Tech. Rep. NE-13. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 185-192.

Results of an inventory of land uses, nature and extent of land management problems, and types of information needed for municipal watersheds are presented.

103. **Dissmeyer, George E.; Swank, Wayne T. 1976.** Municipal watershed management survey. Journal of American Water Works Association. 68(2): 97-100.

Based on survey data, this report provides a general summary of the nature and extent of land uses, management problems, and informational needs for municipal watersheds in the Southeastern United States. Emphasis is placed on small and heavily forested watersheds and related forestry activities.

104. **DiStefano, Robert J.; Neves, Richard J.; Helfrich, Louis A.; Lewis, Mark C. 1991.** Response of the crayfish *Cambarus bartonii bartonii* to acid exposure in southern Appalachian streams. Canadian Journal of Zoology. 69: 1585-1591.

Intermolt adult and juvenile *Cambarus bartonii bartonii* (Fabricius) from Southern Appalachian Mountains streams tolerated considerable acidity when acutely exposed to greatly reduced pH levels in laboratory bioassays. Tolerance increased with increasing size or age of crayfish. Ninety-six-hour exposures yielded LC_{50} values of pH 2.43, 2.56, and 2.85 for adults, advanced juveniles, and early juveniles, respectively. Lowering the water temperature increased the acid tolerance and survival time of intermolt adults during severe acidification (temperatures ranged from 20.2 to 13.3 °C). Acid exposure of intermolt adults in soft water up to 96 hours caused a linear decrease in hemolymph [Na]. Hemolymph [Ca] increased through 48 hours and then returned to near preexposure levels. An initial increase in [K] was followed by a decrease to slightly below preexposure levels. Hemolymph [Mg] remained unchanged. No Ca was lost from carapaces. These observations indicate that occasional episodes of higher than normal acidity in Southern Appalachian streams are not necessarily a threat to intermolt adult and juvenile *C. b. bartonii*. Nevertheless, gradually increasing acidity and loss of watershed buffering capacity could produce sublethal effects such as altered reproductive activity, or changes in early life history stages and more sensitive molt cycle stages, that could damage these populations.

105. **Douglass, James E. 1962.** A method for determining the slope of neutron moisture meter calibration curves. Stn. Pap. 154. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 6 p.

A new water-addition method is presented which allows a check of slope coefficients derived from gravimetric calibrations of neutron moisture probes. Coefficients obtained by the new method differed from those obtained by gravimetric calibration by as much as 36 percent. Differences were attributed to bias arising because drying

temperatures used in gravimetric calibration failed to remove all bound water and because the gravimetric method failed to account for differences in neutron absorption between soils.

106. **Douglass, James E. 1962.** Variance of nuclear moisture measurements. Stn. Pap. 143. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

Several conclusions can be drawn concerning the use of nuclear equipment to measure moisture in Piedmont soils: (1) The error in measuring moisture content is particularly large in soils with varying texture. (2) Analysis of moisture losses, which utilizes covariance techniques to remove the textural effect, is more precise for detecting moisture differences than for determining total moisture content. (3) The error in moisture measurements increases as the range of clay content increases.

107. **Douglass, James E. 1966.** Effects of species and arrangement of forests on evapotranspiration. In: International symposium of forest hydrology; 1965 August 29 - September 10; University Park, PA. Oxford; New York: Pergamon Press: 451-461.

This paper reviews research concerned with the effects of plant species and arrangement on evapotranspiration. In general, grasses use less water than forest species because of the shallower rooting habits of grass; usually, differences in evapotranspiration which occur between forest species could not be detected except where rooting depths were unequal. Evapotranspiration varies with stand density and vegetative height, at least in humid regions, and probably varies with slope and aspect as well.

108. **Douglass, James E. 1966.** Research at the Coweeta Hydrologic Laboratory. In: Conference proceedings - hydrologic activities in the South Carolina region; 1965 March 17-18; Clemson, SC. Clemson, SC: Clemson University: 11-17.

The first 30 years of research at the Coweeta Hydrologic Laboratory and plans for future research are discussed.

109. **Douglass, James E. 1966.** Volumetric calibration of neutron moisture probes. Proceedings, Soil Society of America. 30(5): 541-544.

A volumetric method of estimating the slope (*b*-coefficient) of the calibration curve for a neutron moisture probe is presented. Coefficients obtained for three probes did not differ significantly between soil series or between horizons within a series. Simply dividing the count rate in water by 100 gave a value virtually identical to the b coefficient determined volumetrically for these probes and soils. Agreement was excellent between measured outflow and outflow predicted from neutron measurements made with a volumetrically calibrated probe.

110. **Douglass, James E. 1967.** Man, water, and the forest. Forest Farmer. 26(5): 6-7, 18, 20.

The interrelationships between man's activities, water, and the forest are discussed.

111. **Douglass, James E. 1972.** Annotated bibliography of publications on watershed management by the Southeastern Forest Experiment Station, 1928-1970. Res. Pap. SE-93. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 47 p.

This bibliography contains annotated citations to all publications by the Southeastern Forest Experiment Station on watershed management from 1928 to 1970. Citations are indexed by subject category.

112. **Douglass, J. E. 1973,** reviewer. Small watershed experiments: an appraisal of concepts and research developments. Proceedings, Soil Science Society of America. 37(4): x.

A review of the book authored by L. C. Ward.

113. **Douglass, James E. 1974.** Flood frequencies and bridge and culvert sizes for forested mountains of North Carolina. Gen. Tech. Rep. SE-4. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 21 p.

Equations incorporating watershed area and maximum elevation were developed for discharges at recurrence intervals of 2.33, 5, 10, 20, 30, 40, and 50 years from forested land in the Blue Ridge Province of North Carolina. These equations accounted for 98 percent of the variation in discharge. Capacity tables for several types and sizes of culverts are presented to simplify problems in culvert design.

114. **Douglass, James E. 1974.** Watershed values important in land use planning on southern forests. Journal of Forestry. 72: 617-621.

Forests cover 20 to 65 percent of the land in the major water resource regions of the South, and forest management practices regulate the volume and timing of streamflow from these lands. Although water quality is emerging as the major water problem, quantity and timing of streamflow are also important watershed values which should be considered in land use planning. Protection or improvement of hydrologic performance of forest soils will continue to be an important consideration in planning.

115. **Douglass, James E. 1975.** Southeastern forests and the problem of non-point sources of water pollution. In: Ashton, P. M.; Underwood, R. C., eds. Nonpoint sources of water pollution: Proceedings of the southeastern regional conference; 1975 May 1-2; Blacksburg, VA. Blacksburg, VA: Virginia Polytechnic Institute and State University: 29-44.

Amendments to the Federal Water Pollution Control Act require that nonpoint source pollution from forestry activities be controlled. Erosion is the most serious pollutant originating from forestry activities. Activities which destroy the forest floor and reduce the infiltration

rate of soil cause accelerated erosion. Elevation of water temperature, changing the chemical composition of water and introduction of pesticides and herbicides into streams are other common forms of pollution. Pollution can be minimized by utilizing existing information. Quantification of pollution levels associated with alternative forestry practices and development of new techniques for minimizing non-point source pollution is needed.

116. **Douglass, James E. 1975.** Watershed values important in planning. In: Optimizing the South's forest resources: Proceedings of the 2d regional technical conference; 1974 March 11-15; Houston, TX. Washington, DC: Society of American Foresters: 59-73.

Forests cover 20 to 65 percent of the land in the major water resource regions of the South, and forest management practices control or regulate the volume and timing of streamflow from these lands. Although water quality is emerging as the major water problem, quantity and timing of streamflow are also important watershed values which should be considered in land use planning. Protection or improvement of hydrologic performance of forest soils will continue to be an important consideration in planning.

117. **Douglass, James E. 1977.** Site preparation alternatives: quantifying their effects on soil and water resources. In: Proceedings, site preparation workshop, East; 1977 November 8-9; Raleigh, NC. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southeastern Area State and Private Forestry: 43-45.

Reviews research underway to assess soil erosion from forest roads and soil and nutrient losses from mechanical site preparation and prescribed burning in the Piedmont.

118. **Douglass, James E. 1977.** State of the art in managing water resources on forest land. In: Proceedings, western North Carolina research-resource management conference; 1977 September 14-16; Asheville, NC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 56-60.

This paper deals specifically with the yield, timing, and quality of water flowing from forested watersheds of the Southern Appalachians and how these parameters are changed by management activities.

119. **Douglass, James E. 1980.** Silviculture for water yield. In: Town meeting forestry - issues for the 1980's; 1979 October 15-19; Boston, MA. Washington, DC: Society of American Foresters: 90-96.

A popular misconception exists that forests cannot be managed for improved water yield. To demonstrate the magnitude of forest management impact, the DYNAST-TM model is used to calculate expected changes in water yield from a 6400-acre Southern Appalachian watershed managed for different rotation lengths and size of forest openings.

120. **Douglass, J. E. 1981.** Environmental impacts of weed control alternatives on water. In: Holt, H. A.; Fisher, B. C., eds. Weed control in forest management: Proceedings of the 1981 John S. Wright forestry conference; 1981 February 3-5; West Lafayette, IN. West Lafayette, IN: Purdue University: 220-230.

All weed control methods increase water yield and rate of runoff from watersheds, but their effects on water quality can be grossly different. Properly applied, fire, chemical, and manual methods have least effect on water quality. Conversely, even the best of the mechanical methods increases erosion and thereby reduces water quality. Careful planning and quality workmanship are crucial when mechanical methods are used.

121. **Douglass, James E. 1983.** The potential for water yield augmentation from forest management in the Eastern United States. Water Resource Bulletin. 19(3): 351-358.

High rainfall and extensive forests in the East combine to produce excellent potential for managing forest for increased water yield. Models are presented that allow prediction of streamflow increase from hardwood and pine forests and are being routinely applied in land management planning on National Forests in the Southeast. However, because of the diverse land ownership patterns and the economic objectives of owners, realizing the potential will be difficult at best. The opportunity for realizing the full potential appears greatest where the land is publicly owned.

122. **Douglass, James E. 1983.** A summary of some results from the Coweeta Hydrologic Laboratory. In: Hamilton, Lawrence S.; King, Peter N., eds. Tropical forested watersheds: hydrologic and soils response to major uses or conversions. Appendix B. Boulder, CO: Westview Press: 137-141.

The appendix in this book contains a summary of the effects of tree cutting and timber harvest at the Coweeta Hydrologic Laboratory on timing and distribution of water yield.

123. **Douglass, J. E.; Cochrane, D. R.; Bailey, G. W.; Teasley, J. I,; Hill, D. W. 1969.** Low herbicide concentration found in streamflow after a grass cover is killed. Res. Note SE-108. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 3 p.

Grass cover on an Appalachian watershed was sprayed with atrazine and paraquat and later with atrazine and 2,4-D. Although grass growing in the stream channel was sprayed, atrazine and paraquat levels in water samples were low. During a second application, a 10-foot strip on either side of the channel was left unsprayed; no increase in atrazine and no trace of 2,4-D were detected in streamflow.

124. **Douglass, James E.; Goodwin, O. C. 1980.** Runoff and soil erosion from forest site preparation practices. In: Fraser, Don Lee, comp. U.S. forestry and water

quality: what course in the 80's? Proceedings, 1980 June 19-20; Richmond, VA. Washington, DC: Water Pollution Control Federation: 50-74.

Soil losses and runoff were measured for 3 years after mechanical site preparation treatments were applied on 16 small watersheds in the North Carolina Piedmont. Treatments, which were replicated at four locations, ranged in intensity from a control (undisturbed forest) to KG blading, disking, and planting grass. Runoff increased with intensity of treatment and length of the ephemeral drainage network. Soil loss varied with percentage of ground cover and runoff volume. Erosion varied from 1.0 to 14000 pounds per acre, depending on cover and the ephemeral channel network.

125. **Douglass, J. E.; Hoover, M. D. 1988.** History of Coweeta. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 17-31.

To understand the origin and development of 50 years of research at Coweeta, one must understand the social, economic, and political circumstances as they existed and changed through time. The concern about soil erosion, flood control, and sustained flow of streams as well as future timber supplies led to establishment of the first forest reserves and, ultimately, national forests in the East. There was considerable debate about the influence of forests upon regulation of streamflow and flooding. This chapter traces the history of Coweeta from being a site for forest hydrology and erosion research to being a major site for forest ecosystem research.

126. **Douglass, James E.; Neary, Daniel G. 1980.** Coweeta Hydrologic Laboratory, 1934-2034: past, present, and future. In: The influence of man on the hydrological regime with special reference to representative and experimental basins: Proceedings, Helsinki symposium; 1980 June; Helsinki. Publication 130. Washington, DC: International Association of Scientific Hydrology: 61-65.

Since 1934, the Coweeta Hydrologic Laboratory has served as a primary site for forest hydrological research in the United States. This paper describes the early and current research programs and discusses future research. Water quality and forest productivity are two areas of future concern because of increasing intensity of management and because of shorter rotations and greater utilization of biomass. The growing trend toward short-term studies relating alternative management practices to water quality will continue. Process-level ecosystem research will use the long-term data base of the Coweeta basin to study mineral cycling and evaluate the effects of alternative levels of biomass utilization on forest productivity.

127. **Douglass, James E.; Seehorn, Monte E. 1975.** Forest management impacts on cold water fisheries. In: Symposium on trout habitat research and management: Proceedings; 1974 September 5-6, Cullowhee, NC. Boone, NC: Appalachian Consortium Press: 33-46.

Erosion is the mechanism likely to damage the aquatic resource when a forest is managed. Cutting forests increases streamflow when it is needed most, but conversion from hardwood to pine significantly reduces the size of the aquatic habitat. Herbicides and pesticides are constant threats, but this pollution can usually be prevented. More research is needed to assess the effects on the aquatic community of logging debris, channel clearing, increasing stream temperature from logging along the stream, and changing the nutrient budget of streams by fertilization or silvicultural practices.

128. **Douglass, James E.; Swank, Wayne T. 1972.** Streamflow modification through management of eastern forests. Res. Pap. SE-94. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 15 p.

Equations for predicting the first-year yield increase, duration of the increase, and the total volume of water which occurs from cutting forests are presented. The equations are based on 22 experimental cuttings of hardwood forests in the Appalachian Highlands. The paper also discusses the effects of forest cutting on the seasonal distribution of increased annual flow, stormflow peaks and volumes, and water-quality characteristics.

129. **Douglass, James E.; Swank, Wayne T. 1975.** Effects of management practices on water quality and quantity: Coweeta Hydrologic Laboratory, North Carolina. In: Proceedings of the municipal watershed management symposium; 1973 September 11-12; University Park, PA; September 19-20; Durham, NH. Gen. Tech. Rep. NE-13. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 1-13.

Results from nearly 40 years of watershed experiments at Coweeta are summarized. An equation is presented to predict the annual increase in streamflow from the percentage of basal area cut and from the theoretical extra-terrestrial radiation load for the watershed. Timing of the increased flow from watershed experiments depends on the magnitude of the increase, but results consistently show that much of the increase appears in the low-flow season. Two watershed experiments indicate that conversion of hardwoods to white pine substantially reduces monthly and annual streamflow. Conversion of a hardwood-covered watershed to grass produces up to 5.8 inches of increased flow per year. Although some increase in nutrient export occurs from forest cuttings and species conversions, the increase is well within drinking-water standards.

130. **Douglass, James E.; Swank, Wayne T. 1976.** Multiple use in Southern Appalachian hardwoods - a ten-year case history. In: Proceedings of the 16th International Union of Forestry Research Organizations World Congress; 1976 June 20 - July 2; Oslo, Norway. Vienna, Austria: IUFRO Secretariat: 425-436.

The multiple use concept of managing hardwood forests in the Southern Appalachians for timber, water, wildlife,

and recreation was pilot-tested on a 144-ha watershed in western North Carolina. Water, timber, and wildlife objectives of management were achieved, and responses of these resources during the first 10 years of management are discussed. Log dams designed to create riffles and pools caused the greatest conflict with other objectives by increasing turbidity of water, causing excessive channel and bank cutting, and probably adversely affecting trout, at least temporarily.

131. **Douglass, J. E.; Swift, L. W., Jr. 1977.** Forest Service studies of soil and nutrient losses caused by roads, logging, mechanical site preparation, and prescribed burning in the Southeast. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 489-502.

New studies of soil and nutrient pollution of streams caused by woods roads, log skidding, mechanical site preparation, and prescribed burning are described for the Piedmont and Appalachian Mountains. Proportional samples for sediment and nutrient analysis are collected by 2-foot Coshocton wheels. Objectives of nonpoint-source pollution studies are to establish baseline levels of soil and nutrient loss, determine increases in losses due to certain forestry practices, and develop methods of estimating losses for other practices and other locations.

132. **Douglass, James E.; Van Lear, David H. 1983.** Prescribed burning and water quality at ephemeral streams in the Piedmont of South Carolina. Forest Science. 29(1): 181-189.

Soil and nutrient export were monitored before and after two prescribed burns 18 months apart on four pairs of treatment and control watersheds. Burns were designed to prepare Piedmont pine stands for regeneration. The burns did not significantly affect storm runoff, sediment concentrations, or sediment export from the watersheds. No significant change in NO_3-N, NH_4-N, Ca, Mg, or K concentrations or export occurred after either burn. Sodium concentration before burning was significantly different for the burned-unburned watershed pairs but not significant after either prescribed burn. This difference was attributed to factors other than burning. It was concluded that the two prescribed burns did not change water quality of the streams studied.

133. **Douglass, James E.; Van Lear, David H.; Valverde, Carmen. 1983.** Stormflow changes after prescribed burning and clearcutting pine stands in South Carolina Piedmont. In: Jones, Earle P., Jr., ed. Proceedings of the 2d biennial southern silvicultural research conference; 1982 November 2-4; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 454-460.

Four small pine-covered watersheds in the South Carolina Piedmont were prescribe-burned in September 1979 and clearcut 3 months later. Peak discharge and stormflow increased significantly on three of the watersheds. Relative increases were greater than those reported for larger watersheds, but were smaller than those to be expected from mechanical site preparation. Time to peaking and duration of stormflow were not significantly affected.

134. **Drooz, A. T.; Fedde, G. F.; Copony, J. A. 1976.** Egg parasite of the elm spanworm is not *Telenomus alsophilae*. Environmental Entomology. 5(3): 492-494.

When *Telenomus alsophilae* (Viereck) was reported as attacking eggs of the fall cankerworm, *Alsophila pometaria* (Harris), and the elm spanworm, *Ennomos subsignarius* (Hubner), differences in parasite ovipositional behavior on the eggs of the two hosts were observed. These observations, field and laboratory tests, and reexamination of specimens submitted for specific determination indicate that *T. alsophilae* attacks eggs of the fall cankerworm and *T.* n. sp. parasitizes eggs of the elm spanworm.

135. **Dunford, E. G.; Fletcher, P. W. 1947.** Effect of removal of stream-bank vegetation upon water yield. Transactions, American Geophysical Union. 28: 105-110.

This is a preliminary report on the results of removing stream-bank vegetation from Watershed 6 at the Coweeta Hydrologic Laboratory. Diurnal fluctuations in the streamflow were virtually eliminated. Cutting of riparian growth also resulted in an increase in yield of sufficient magnitude to be significant in water resource management.

136. **Dyer, M. I.; Crossley, D. A., Jr. 1989.** Linking ecological networks and models to remote sensing programs. In: Botkin, Daniel B.; Caswell, Margriet F.; Estes, John E.; Orio, Angelo A., eds. Changing the global environment: perspectives on human involvement. Boston, MA: Academic Press, Inc: 271-282.

Developments in technology of remote sensing are at a stage where those methods can be applied to large-scale environmental issues, but the ability to attribute the images to specific features on the Earth's surface or extend conclusions to general conditions at other locations has lagged behind. We have the ability to engineer extremely capable satellite and remote sensing systems and have gained enormous insight into how ecological associations come together and function, but scientists have found it difficult to couple the two subjects. At a workshop in Athens, GA, in 1985, representatives from four Man and the Biosphere Reserves and NASA met to consider research to develop links between remote sensing and ecological principles. This chapter summarizes a program design resulting from that workshop.

137. **Edwards, C. A.; Reichle, D. E.; Crossley, D. A., Jr. 1970.** The role of soil invertebrates in turnover of organic matter and nutrients. In: Reichle, D. E., ed. Analysis of temperate forest ecosystems. Berlin; Heidelberg; New York: Springer-Verlag: 147-172.

This chapter discusses the role of soil invertebrates in the breakdown of litter, woody materials, and roots. Various

methods of studying litter are presented. Energy flow and nutrient cycles through soil populations and net production by animals of different trophic levels are also examined.

138. **Edwards, Lorraine. 1979.** The greening of a clearcut. Research Reporter. 12(3): 6-8.

An article discussing research on clearcut regrowth, focusing on nutrient conservation and distribution.

139. **Elliott, Katherine J.; Clinton, Barton D. 1993.** Equations for estimating biomass of herbaceous and woody vegetation in early-successional Southern Appalachian pine-hardwood forests. Res. Note SE-365. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Allometric equations were developed to predict aboveground dry weight of herbaceous and woody species on prescribe-burned sites in the Southern Appalachians. Best-fit least-square regression models were developed using diameter, height, or both as the independent variables and dry weight as the dependent variable. Coefficients of determination for the selected total biomass models ranged from 0.620 to 0.992 for herbaceous species and from 0.698 to 0.999 for the woody species. Equations for foliage biomass generally had lower coefficients of determination than did equations for either stem or total biomass of woody species.

140. **Elliott, Katherine J.; Loftis, David L. 1993.** Vegetation diversity after logging in the southern Appalachians. Letter *in* Conservation Biology. 7(2): 220-221.

Rebuttal letter re: Durry, David C.; Meier, Albert J. 1992. Do Appalachian herbaceous understories ever recover from clearcutting? Conservation Biology. 6: 196-201.

141. **Elliott, Katherine J.; Vose, James M. 1994.** Photosynthesis, water relations, and growth of planted *Pinus strobus* L. on burned sites in the southern Appalachians. Tree Physiology. 14: 439-454.

Physiology and growth of *Pinus strobus* L. seedlings were measured two years after planting on two clearcut and burned sites in the Southern Appalachians. Multiple regression analysis was used to relate seedling net photosynthesis to vapor pressure deficit, seedling crown temperature, photosynthetically active radiation (PAR), needle N, xylem water potential, and soil water. Analysis also related seedling size and growth to average net photosynthesis, leaf conductance, cumulative xylem water potential, soil water, needle N, seedling temperature, and PAR. Seedling net photosynthesis was significantly related to vapor pressure deficit, midday water potential, crown temperature, and PAR early in the growing season with vapor pressure deficit alone explaining 42 percent of the variation. As neighboring vegetation developed, light became more limiting and significantly reduced seedling net photosynthesis later in the growing season. Final seedling diameter was significantly related to competitor biomass, average photosynthetic rate, and needle N.

142. **Elliott, Katherine J.; Vose, James M. 1993.** Site preparation burning to improve southern Appalachian pine-hardwood stands: photosynthesis, water relations, and growth of planted *Pinus strobus* L. during establishment. Canadian Journal of Forest Research. 23: 2278-2285.

We examined the physiological performance and growth of *Pinus strobus* L. seedlings the first growing season after planting on two clearcut and burned sites in the Southern Appalachians. Growth of the seedlings was related to physiological measurements (net photosynthesis(P_N), transpiration, leaf conductance, and xylem water potential), soil water, foliar N, seedling temperature, and light environment using regression analysis. Diameter growth increased with increasing foliar N concentration and decreased as competitor biomass increased. Competition reduced growth by lowering foliar N, shading seedlings, and possibly reducing photosynthetic capacity. Increased temperature and lower available soil water may obscure these relationships on a harsh site.

143. **Evans, James O.; Patric, James H. 1983.** Harvest trees, reap water. Journal of Soil and Water Conservation. 38: 390-392.

The relationship of timber harvesting to water yield is discussed by the authors. They trace the development of current knowledge that clearcutting increases water yield from the earlier idea that an intact forest maximizes water yield. Experimental results from eastern and western watersheds are presented, along with implications for timber management as a tool for manipulating water yield.

144. **Fahey, Timothy J., reviewer. 1988.** Forest hydrology and ecology at Coweeta. The Quarterly Review of Biology. 63: 478-479.

A review of the Coweeta Symposium volume.

145. **Farmers Federation News. 1951.** The Coweeta story. Farmers Federation News. 31(12): 9, 44-45, 48.

Reasons for establishment of the Coweeta Hydrologic Laboratory are given, the research area is described, and studies concerning the effects of mountain farming, woodland grazing, and cutting of vegetation on streamflow are discussed.

146. **Ffolliott, Peter F.; Swank, Wayne T., eds. 1986.** Potentials of noncommercial forest biomass for energy. Tech. Bull. 256. Tucson, AZ: University of Arizona, School of Renewable Natural Resources. 40 p.

An international workshop was held to examine the use of forest biomass for energy applications on a worldwide basis. It considered socioeconomic, energy, and environmental issues associated with utilizing forests for fuel and organics. A primary recommendation was to assess, by inventory methods, the biomass in forests, trees, and shrublands; the trends in current use of these resources for whatever purposes; and the productive potential of the lands.

147. **Ffolliott, Peter F.; Swank, Wayne T., eds. 1991.** People and the temperate region: a summary of research from the United States Man and the Biosphere Program 1991. Publication 9838. Washington, DC: U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs. 65 p. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; PB 91-126813]

This report represents a summary of the importance of MAB-sponsored research in filling in gaps of knowledge and understanding of the structure and function of ecosystems and the impacts upon ecosystems of different types of human interventions. The results of 12 projects are summarized in this report to illustrate the broad range of support by the U.S. MAB Program for management- and policy-related research on environmental issues in temperate regions.

148. **Findlay, Stuart; Meyer, Judy L. 1984.** Significance of bacterial biomass and production as an organic carbon source in lotic detrital systems. Bulletin of Marine Science. 35(3): 318-325.

Bacteria are an organic carbon source for secondary consumers in detritus-based ecosystems, but few measurements of bacterial production are available. The use of tritiated thymidine has made possible measurement of bacterial production. We have found bacterial production in sediments and on particulate detritus of two lotic ecosystems to range from 0.01-10.0 mg $C/m^2/d$. These rates are only a small proportion of carbon entering these systems. Also, bacterial carbon production is small relative to total carbon mineralization, indicating either that other organisms are responsible for the bulk of catabolic activity or that bacterial utilization of detritus in these systems is very inefficient in the sense that the majority of carbon assimilated is respired rather than allocated to new growth.

149. **Findlay, Stuart; Meyer, Judy L.; Smith, Philip J. 1986.** Incorporation of microbial biomass by *Peltoperla sp.* (Plecoptera) and *Tipula sp.* (Diptera). Journal of North American Benthological Society. 5(4): 306-310.

The quantitative contribution of microbial carbon to the nutrition of aquatic detritivores previously has not been measured. Using radiotracers to specifically label bacteria and fungi on leaf litter, we determined the rate of incorporation of bacteria and a hyphomycete by larvae of stonefly and incorporation of bacteria by larvae of cranefly. Incorporation of bacterial carbon accounted for less than 1 percent of the carbon respired by either insect. Incorporation of fungal carbon was greater but still only 25 percent of the carbon respired by the stonefly larva.

150. **Fitzgerald, J. W.; Andrew, T. L. 1984.** Mineralization of methionine sulfur in soils and forest floor layers. Soil Biology and Biochemistry. 16(6): 565-570.

A1-horizon soils and O1, O2 forest floor layers from a mixed mature hardwood forest rapidly changed methionine-S to readily available (salt-extractable) and less readily available (acid- and base-extractable) inorganic sulphate. This latter conversion represents the incorporation into organic matter of a portion of the SO_4 released by mineralization. On a dry weight basis, the O2 layer of the forest floor was the most active with respect to both conversions. Moreover, capacities for mineralization and SO_4 incorporation decreased with increasing sample depth within the mineral horizon. Both conversions were dependent upon temperature and duration of incubation.

151. **Fitzgerald, J. W.; Andrew, T. L. 1985.** Metabolism of methionine in forest floor layers and soil: influence of sterilization and antibiotics. Soil Biology and Biochemistry. 17(6): 881-883.

Antibiotics were added to forest soils to separate and define incorporation and mineralization processes involving the amino acid L-methionine. Data presented reveal that both processes are microbially mediated.

152. **Fitzgerald, J. W.; Andrew, T. L.; Swank, W. T. 1984.** Availability of carbon-bonded sulfur for mineralization in forest soils. Canadian Journal of Forest Research. 14: 839-843.

The capacities of soil from hardwood, clearcut, and pine forests to mineralize, adsorb, and incorporate into organic matter carbon-bonded sulfur in the form of L-methionine was investigated. These soils adsorbed and incorporated between 40 and 66 percent of this amino acid within a 0.5-hour incubation period, but much of the immobilized sulfur was mineralized after 48 hours incubation. On the forested watershed, the O2 layer exhibited the highest levels of activity. Incorporation of methionine into organic matter was complete within about 12 h of incubation and was inhibited by pretreatment of the samples with sodium azide, a general inhibitor of cell respiration. The capacities for methionine incorporation, determined by laboratory assays, complement observations of the high levels of carbon bonded sulfur found in situ in forest litter and soil.

153. **Fitzgerald, J. W.; Ash, J. T.; Strickland, T. C.; Swank, W. T. 1983.** Formation of organic sulfur in forest soils: a biologically mediated process. Canadian Journal of Forest Research. 13: 1077-1082.

We investigated the ability of forest soils to incorporate sulfur from added inorganic sulfate into salt-extractable and non-salt-extractable forms. At least 65 percent of the added sulfate was adsorbed while 8 to 27 percent of the sulfate added was recovered only after treatment of salt-extracted samples with acid and base. The incorporation of sulfur into this latter fraction was incubation time, temperature and depth dependent, and exhibited both spatial as well as seasonal variation in samples taken along a transect of one of the watersheds. Sulfur incorporation was inhibited by sodium azide, erythromycin and candicidin, suggesting that the incorporation of sulfur into the non-salt-extractable fraction is mediated by bacteria and fungi.

154. **Fitzgerald, J.W.; Autry, A.R. 1992.** Organic sulfur dynamics including mineralization and immobilization of various organic fractions. In: Johnson, Dale W.; Lindberg, Steven E., eds. Atmospheric deposition and forest nutrient cycling: a synthesis of the Integrated Forest Study. Ecological Studies, vol. 91. New York: Springer-Verlag: 118-129.

The role of organic sulfur transformations is summarized for 10 sites of the Integrated Forest Study, including the Coweeta pine and Coweeta hardwood sites. Both Coweeta sites fell within the lower range of organic sulfur content, yet the organic sulfur component represented 63 percent of total sulfur in the pine site and 83 percent in the hardwood. Thirteen sites were ranked with respect to potential for formation and accumulation of organic S, with the Coweeta hardwood site being near midrange. Article lists 194 citations.

155. **Fitzgerald, J. W.; Hale, D. D.; Swank, W. T. 1988.** Sulphur-containing amino acid metabolism in surface horizons of a hardwood forest. Soil Biology and Biochemistry. 20(6): 825-831.

The O1, O2 and A1 horizons of a hardwood forest mineralized and incorporated into organic matter ^{35}S-labeled cysteine and methionine. Based upon seasonal assays, mineralization was the dominant process for cysteine. With methionine, the reverse was true except in the A1 horizon. Analysis for existing amounts of organic S revealed that carbon-bonded S was a major component throughout the year in all horizons. This S pool consisted of sulphonate S and amino acid S. Sulphonate represented 59, 44, and 28 percent of total S in the O1, O2 and A1 horizons, respectively. Amino acid S comprised 22, 24, and 15 percent of the total S in these horizons. In samples, decreases in existing amounts of amino acid S coincided with increases in cysteine mineralization suggesting that cysteine is an important component of the S pool in the A1 horizon.

156. **Fitzgerald, J. W.; Johnson, D. W. 1982.** Transformations of sulphate in forested and agricultural lands. In: More, A. I., ed. Proceedings of the conference: sulphur '82 international conference; 1982 November 14-17; London. London: British Sulphur Corp. Ltd.: 414-426. Vol. 1.

The physiochemical and biological fates of exogenous inorganic sulphate in agricultural and forest soils were considered. Emphasis was given to the capacities of these soils to adsorb sulphate and to convert the sulphur of the remaining nonadsorbed anion into soil organic sulphur. While agricultural and forest systems can differ substantially in capacity for sulphate adsorption, both systems can incorporate sulphate as ester sulphate into organic matter. Ester-linked sulphur may also represent the form of soil organic sulphur which is reconverted to inorganic sulphate in response to plant growth. Existing evidence suggests that the formation of soil organic sulphur is regulated by energy availability, whereas the reconversion process may be dictated by levels of available inorganic sulphate.

157. **Fitzgerald, J. W.; Strickland, T. C. 1987.** Mineralization of organic sulphur in the O2 horizon of a hardwood forest: involvement of sulphatase enzymes. Soil Biology and Biochemistry. 19(6): 779-781.

Sulphate-S is accumulated in organic matter in soil of deciduous forests. Once organic-S is formed, it can become mineralized by one of two mechanisms: oxidation of the carbon skeleton to yield energy and carbon for biosynthesis with SO_4 being released as a byproduct, or directly after hydrolysis of ester-sulphate linkages comprising the organic-S. In order to obtain direct evidence for the involvement of enzymes, S mineralization occurring in organic matter extracts was assayed in the presence and absence of PO_4 and sodium azide. The latter compound inhibits microbial growth but not sulphatase activity. Because SO_4 was released in the presence of azide, enzymes must have been present in the extract before incubation. Further, microbial growth was not required to sustain enzyme activity, suggesting that S mineralization is mediated by preformed, possibly extracellular, enzymes.

158. **Fitzgerald, J. W.; Strickland, T. C.; Ash, J. T. 1985.** Isolation and partial characterization of forest floor and soil organic sulfur. Biogeochemistry. 1: 155-167.

The formation of organic sulfur from inorganic sulfate was investigated in hardwood forest floor and mineral horizons. All samples converted sulfate-sulfur into a non-salt-extractable form which was recoverable only under conditions which release organic matter. This conversion was inhibited by azide, by erythromycin, candicidin, chloramphenicol and tetracycline. The form of sulfur generated in the O2 forest floor layer and in A1-horizon soil was characterized as having an average C:N:S ratio of 103:6:1. The ester sulfate content of the O2 extract was about 60 percent. Reduction yielded lower estimates of ester sulfate for two of the three soil extracts analyzed. The electrophoretic heterogeneity of all extracts suggests that some may contain stable ester linkages that hydrolyze only after prolonged treatment and that the standard procedure for hydriodic acid reduction may provide conditions of temperature and contact time with the acid which are insufficient for the release of sulfate from these esters.

159. **Fitzgerald, J. W.; Strickland, T. C.; Swank, W. T. 1982.** Metabolic fate of inorganic sulfate in soil samples from undisturbed and managed forest ecosystems. Soil Biology and Biochemistry. 14: 529-536.

Surface soils from four watersheds located at the Coweeta Hydrologic Laboratory were found to rapidly convert exogenous $^{35}SO_4$ into nonextractable ester sulphate and carbon bonded-sulphur. A substantial proportion of the added $^{35}SO_4$ remained adsorbed in all samples but was fully released after sequential leaching with 1M Na_2SO_4, NaH_2PO_4 and LiCl. This extraction procedure also released a number of ^{35}S-labeled metabolites and some of these have been identified on the basis of coelectrophoresis and cochromatography with authentic standards. Recoveries of ^{35}S suggest that all samples were capable

of volatilizing some of the added SO_4 but only after prolonged incubation. The results support the possibility that S accumulation in these watersheds is related to SO_4 adsorption. The results also indicate that future research should address incorporation of S into nonextractable organic forms.

160. **Fitzgerald, J. W.; Swank, W. T.; Strickland, T. C.; Ash, J. T.; Hale, D. D.; Andrew, T. L.; Watwood, M. E. 1988.** Sulfur pools and transformations in litter and surface soil of a hardwood forest. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 245-253.

Work on sulfur transformations was initiated at Coweeta in 1980 in an effort to determine the relevance of the plant sulfolipid as a source of sulfate in forest soil. Data reported in this chapter are based upon analyses of samples taken along a transect of WS 18 established at mid-elevation on the catchment in May 1982. The results of this study showed that A-horizon soil from several watersheds exhibited not only rapid S-mineralization rates for this compound, but samples also rapidly incorporated a substantial portion of the released sulfate into a fraction which could only be recovered by acid extraction. This work was followed closely by a study of the fate of sulfate in soils of several forested ecosystems.

161. **Fitzgerald, J. W.; Watwood, M. E. 1988.** Amino-acid metabolism in forest soil - isolation and turnover of organic matter covalently labelled with ^{35}S-methionine. Soil Biology and Biochemistry. 20(6): 833-838.

Interconversions between sulfate and organic S will influence the mobility of inorganic sulfate, a major anionic component of acidic precipitation. Organic matter was extracted from the O2 horizon of a hardwood forest and exposed to ^{35}S-methionine for 18 hours to allow incorporation of the amino-acid into the extract. This material was chemically recalcitrant, requiring treatment for 6 hours at 121 °C with 6 M NaOH for complete release of the incorporated methionine. A and B horizon soils from several forests were exposed to labeled material following dialysis to remove unlabeled components and a minor ^{35}S-labeled component. Samples began to release ^{35}S-methionine after 48 hours. Further metabolism of this amino-acid included mineralization and conversion to cysteine. A portion of the sulfate-S from mineralization was incorporated into organic matter and recovered only by acid and alkali extraction. ^{35}S-labeled methionine and cysteine were also found in these latter fractions, indicating that these amino-acids had been directly incorporated into organic material during exposure.

162. **Fitzgerald, J. W.; Watwood, M. E.; Rose, F. A. 1985.** Forest floor and soil arylsulphatase: hydrolysis of tyrosine sulphate, an environmentally relevant substrate for the enzyme. Soil Biology and Biochemistry. 17(6): 885-887.

Arylsulphatase is an enzyme widespread in nature that catalyzes the release of SO_4 from sulfate esters of simple phenols. Although this enzyme is found extensively in soil, its activity has not been successfully correlated with S mineralization rates. A typical assay substance is not found in nature. Various tests show that microbial growth was necessary to sustain enzyme production and activity while fungal growth was not.

163. **Flavell, T. H.; Lambert, H. L. 1970.** The fall cankerworm: an evaluation of an epidemic population adjacent to the Coweeta Hydrologic Laboratory, North Carolina. Rep. 70-1-45. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Area, State and Private Forestry, Division of Forest Pest Control. 7 p.

The fall cankerworm is epidemic over an 800-acre area on the Standing Indian Wildlife Refuge near Franklin, NC. The infestation has now spread slightly onto the research watersheds of the Coweeta Hydrologic Laboratory. Defoliation is expected to be moderate to heavy in the infested area, but the area of defoliation on the research watershed is not expected to exceed the Laboratory's tolerance level. Direct control measures are not deemed necessary at this time.

164. **Forest Farmer. 1956.** We learn about little waters of Coweeta. Forest Farmer. 16(2): 20-21.

Experiments at Coweeta are pictorially described.

165. **Fox, T. R.; Burger, J. A.; Kreh, R. E.; Douglass, J. E. 1983.** An overview of watershed and nutrient cycling research at the Reynolds Homestead Research Center. In: Jones, Earle P., Jr., ed. Proceedings of the second biennial southern silvicultural research conference; 1982 November 2-4; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 468-476.

Preliminary results of a study of changes brought about by clearcut harvesting and site preparation in the Virginia Piedmont are described. Three watersheds were commercially clearcut during 1981 and a fourth remained undisturbed as a control. Site treatments were: chop and burn; sheardisk (1 pass); and shear, rake-pile, disk (3-pass), representing three levels of site preparation intensity.

166. **Franklin, J. F. 1988.** Past and future of ecosystem research - contribution of dedicated experimental sites. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 415-424.

Most fields of science seem to profit disproportionately from the central role of one or a few outstanding institutions. This symposium recognizes one such institution, the Coweeta Hydrologic Laboratory. This chapter contains some personal observations on ecological research during the last 15 years, with particular reference to the role that has been played by Coweeta and

similar sites. The author considers accomplishments in ecosystem research, factors that have contributed to these accomplishments, and implications for future progress in ecological research.

167. **Freeman, M. C.; Crawford, M. K.; Barrett, J. C.; Facey, D. E.; Flood, M. G.; Hill, J.; Stouder, D. J.; Grossman, G. D. 1988.** Fish assemblage stability in a Southern Appalachian stream. Canadian Journal of Fisheries and Aquatic Sciences. 45: 1949-1958.

Fish populations were monitored at three sites in a Southern Appalachian stream for 40 months. At two sites, relative species abundances and production were persistent due to low variation in abundance of the two numerically dominant fishes, mottled sculpins (*Cottus bairdi*) and longnose dace (*Rhinichthys cataractae*). Less abundant residents, rosyside dace (*Clinostomus funduloides*), rainbow trout (*Salmo gairdneri*), and greenside darters (*Etheostoma blennioides*), displayed lower levels of persistence. Pronounced annual variation in young-of-the-year recruitment or subsequent year-class strength of four resident species possibly resulted from a severe drought in the third year. The three-species assemblage at a third site also was persistent as a result of relatively stable sculpin and longnose dace populations, whereas the rainbow trout population fluctuated among years. Significant intersite differences in year-class strength and population structures suggest that spatial variation in habitat characteristics affected assemblage dynamics and responses to environmental fluctuations.

168. **Freeman, Mary C.; Stouder, Deanna J. 1989.** Intraspecific interactions influence size specific depth distribution in *Cottus bairdi*. Environmental Biology of Fishes. 24(3): 231-236.

Depth selection by different sizes of mottled sculpin, *Cottus bairdi*, was tested in a Southern Appalachian stream. Field observations indicated that, during 1 hour periods, both small and large individuals move within an area less than 0.50 m^2. Individuals of both sizes, placed in field enclosures, preferred deep microhabitat. When large fish were placed in cages with small fish, small fish initially spent more time in slope and shallow microhabitats. Average interfish distances were not correlated with their absolute size differences, suggesting *C. bairdi* interactions may involve both predation and competition. In streams, size-related differences in microhabitat depth may result more from intraspecific interactions than from size-specific depth preferences.

169. **Fry, Brian. 1991.** Stable isotope diagrams of freshwater food webs. Ecology. 72(6): 2293-2297.

Stable carbon and nitrogen isotopes were used to survey how organic matter is cycled in Coweeta forests and 16 other LTER ecosystems. Nitrogen isotope measures indicated trophic level and carbon isotopes indicated which plants were important sources of nutrition. Plant and soil samples contributed by Coweeta were used to define the generality of ^{15}N values across ecosystems.

170. **Gaskin, Julia W.; Douglass, James E.; Swank, Wayne T., compilers. 1984.** Annotated bibliography of publications on watershed management and ecological studies at Coweeta Hydrologic Laboratory, 1934-1984. Gen. Tech. Rep. SE-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 140 p.

This bibliography spans 50 years of research at Coweeta from 1934 through part of 1984 and also includes earlier papers written at the Appalachian Station before the establishment of Coweeta. It is a modification and update of two previous compilations of research results and contains 470 citations, including a separate section on theses and dissertations. Papers were included if authored by Forest Service and other Federal scientists, university faculty and students, or other individuals who conducted research in the Coweeta Basin, utilized Coweeta data in their analyses, or were partially supported either with funding or other assistance by the Southeastern Forest Experiment Station or the Appalachian Forest Experiment Station.

171. **Gaskin, J. W.; Dowd, J. F.; Nutter, W. L.; Swank, W. T. 1989.** Vertical and lateral components of soil nutrient flux in a hillslope. Journal of Environmental Quality. 18: 403-410.

The vertical and lateral components of chemical flux during storm events were investigated in a Typic Hapludult to assess their importance in understanding the effects of atmospheric deposition on hillslope sites. Throughfall, stemflow, forest floor leachate, and soil solution from the BA, Bt, and BC horizons were sampled and analyzed for SO_4,NO_3-N, Cl, HCO_3, H, K, Ca, Mg, and Na. Total lateral flow as a ratio of total vertical flow averaged 0.23 and 0.30 in the A and BA horizons, respectively, indicating lateral fluxes were an important path of nutrient movement in the surface horizons. Fluxes of all ions except HCO_3, NO_3-N, and H peaked in the forest floor leachate and the BA soil solution, then decreased with depth. Decreases of SO_4 flux between the BA and BC horizons could not be explained by the lag of solute movement or by lateral solute losses, demonstrating the system was an effective $S0_4$ sink.

172. **Gentry, John B.; Odum, Eugene P.; Mason, Marc; Nabholz, Vince; Marshall, Samuel; McGinnis, John T. 1968.** Effect of altitude and forest manipulation on relative abundance of small mammals. Journal of Mammalogy. 49(3): 539-541.

Twenty-seven trapping lines were run over a 2500-foot altitude gradient on disturbed and undisturbed watersheds at Coweeta to test the hypothesis that the frequency of small mammals increases with increasing altitude. The results confirmed the hypothesis. There were no significant differences between disturbed and undisturbed watersheds, but differences in the varieties of species were noted.

173. **Georgian, Theodore J.; Wallace, J. Bruce. 1981.** A model of seston capture by net-spinning caddisflies. Oikos. 36: 147-157.

Six species of net-spinning caddisflies (Trichoptera) coexist in the headwater region of the Tallulah River, feeding on suspended organic matter (seston) captured by their nets. Data on net mesh sizes, microhabitat preferences, etc., were incorporated into a model of seston capture. Results indicate that these coexisting caddisflies do not reduce competition by partitioning available food by particle size. The model predicts annual seston capture far exceeding (1000 X) annual production by the six species. It is suggested that availability of high-quality food items (primarily drifting animals) is limiting to these filter-feeders, rather than overall seston supply.

174. **Georgian, Ted; Wallace, J. Bruce. 1983.** Seasonal production dynamics in a guild of periphyton-grazing insects in a Southern Appalachian stream. Ecology. 64(5): 1236-1248.

Temporal partitioning has been found to be a predominant mode of ecological segregation among groups of systematically related stream insects. This concept was extended to a functionally similar but systematically diverse group of species. The life cycles and secondary production of six species of periphyton-grazing insects (scrapers) were studied in a fourth-order unshaded stream reach in the southern Appalachian Mountains. The production peaks of the six species occurred at separate points in the year, with very little overlap between species and were significantly more regularly spaced than would be expected by chance alone. The patterns of temporal organization observed in this group of species were linked with specialized life histories.

175. **Georgian, Ted; Wallace, J. Bruce. 1984.** Seasonal production dynamics of six species of periphyton-grazing stream insects. BioScience. 34(1): 42-43.

A condensation of "Seasonal Production Dynamics in a Guild of Periphyton-Grazing Insects in a Southern Appalachian Stream." Ecology. 64(5): 1236-1248.

176. **Gist, C. S.; Crossley, D. A., Jr. 1975.** Feeding rates of some cryptozoa as determined by isotopic half-life studies. Environmental Entomology. 4: 625-631.

Rates of ingestion were measured for nine groups of invertebrate cryptozoans, utilizing radioactive tracer turnover rate measurements. These groups were Diplopoda, Cryptostigmata, Pulmonata, Mesostigmata, Collembola, Orthoptera, Coleoptera, and two groups of Araneida. The radioisotopes ^{134}Cs and ^{85}Sr were considered as the metabolic analogs of potassium and calcium, respectively. Feeding rates were calculated as the ingestion necessary to maintain body pools of these elements. Values obtained were somewhat lower than results reported by others, possibly due to inflated estimates of assimilation for the radioisotopes.

177. **Gist, Clayton S.; Crossley, D. A., Jr. 1975.** The litter arthropod community in a Southern Appalachian hardwood forest: numbers, biomass and mineral element content. American Midland Naturalist. 93: 107-122.

The biomass, numbers of individuals and mineral content of the arthropod fauna in the litter of a mixed hardwood forest were examined. The biomass values of the litter arthropods were generally higher than in other forests. Possible reasons for higher biomass values are discussed. Potassium and calcium standing crops are compared to those of a *Liriodendron* forest in Tennessee. With few exceptions the potassium values are comparable. However, there appear to be great differences in the calcium values.

178. **Gist, C. S.; Crossley, D. A., Jr. 1975.** A model of mineral-element cycling for an invertebrate food web in a southeastern hardwood forest litter community. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symp. Ser. Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 84-106. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

A 10-compartment model of the movement of calcium and potassium through a selected cryptozoan food web was constructed. The fluxes of potassium and calcium between the compartments were estimated using radioactive tracers. Results indicated that the models based on the summer states of the systems overemphasized the contribution of mesofauna to litter decomposition. On the basis of the annual nutrient models, Cryptostigmata and Collembola were the most important saprovores and small Araneida and Mesostigmata were the most important predators. The biomass model based on calcium fluxes showed that saprovores accounted for 20 percent of the total annual input; this agrees with the literature.

179. **Gist, Clayton S.; Swank, Wayne T. 1974.** An optical planimeter for leaf area determination. American Midland Naturalist. 92: 213-217.

An optical planimeter for determining leaf area is presented. The system proposed is simple and easily used, compact and somewhat portable, accurate and species-independent with respect to estimates of leaf area. Calibration and tests have shown the system exhibits a linear response to changes in leaf area.

180. **Golladay, S. W.; Webster, J. R. 1988.** Effects of clear-cut logging on wood breakdown in Appalachian Mountain streams. The American Midland Naturalist. 119(1): 143-155.

Red oak sticks, approximately 10-cm long and in three size classes were placed in two second-order streams at Coweeta. Big Hurricane Branch drains a watershed logged in 1976 (WS7), while Hugh White Creek drains an uncut reference watershed (WS14). Sticks were collected at 6-month to 1-year intervals from September 1981 through November 1985. Breakdown rates were significantly different among size classes on both watersheds; smaller sticks lost mass faster than larger sticks. Breakdown rates of similar size sticks were significantly faster in the disturbed stream than in Hugh White Creek. Faster rates

of wood breakdown in Big Hurricane Branch may be associated with higher stream NO_3-N levels, greater stream channel instability and greater invertebrate abundance on sticks.

181. **Golladay, S. W.; Webster, J. R.; Benfield, E. F. 1983.** Factors affecting food utilization by a leaf shredding aquatic insect: leaf species and conditioning time. Holarctic Ecology. 6: 157-162.

Gravimetric feeding studies were used to examine the feeding strategy of *Pteronarcys proteus* (Plecoptera) using unconditioned, 1-month conditioned, and 2-month conditioned deciduous leaves of four species. Assimilation efficiencies of *Pteronarcys* nymphs feeding on unconditioned and conditioned leaf material ranged from 13.4 to 21.9 percent ash-free dry weight of leaf material, indicating that *Pteronarcys* was able to digest and assimilate leaf material. Assimilation efficiences did not change as leaf material conditioned, which suggests that assimilation efficiency does not accurately reflect changes in detrital food quality. However, as leaves conditioned, the ingestion rate of *Pteronarcys* nymphs accelerated. Assimilation rates of *Pteronarcys* nymphs varied in a pattern similar to ingestion rates. This reflects the importance of ingestion rate in the feeding response of *Pteronarcys*.

182. **Golladay, S. W.; Webster, J. R.; Benfield, E. F. 1987.** Changes in stream morphology and storm transport of seston following watershed disturbance. Journal of North American Benthological Society. 6(1): 1-11.

Particulate organic matter (seston) was sampled during baseflows and stormflows in streams draining an 8-year-old clearcut, a 25-year-old clearcut, and two reference watersheds. There were fewer debris dams and organic matter accumulations in disturbed streams. Baseflow seston concentrations varied seasonally, increasing during summer, but did not differ consistently between streams. In all streams, seston concentration increased with increasing discharge during storms, decreased during peak flows, and gradually declined as discharge returned to baseflow. Average seston concentrations during storms were generally highest in streams draining disturbed watersheds. Storm transport varied with season, storm intensity, and storm duration. Results show that baseflow seston concentrations in streams draining disturbed areas may return to normal levels within a few years following disturbances; however, concentrations during storms may remain elevated for many years.

183. **Golladay, S. W.; Webster, J. R.; Benfield, E. F. 1989.** Changes in stream benthic organic matter following watershed disturbance. Holarctic Ecology. 12: 96-105.

Comparisons of organic matter inputs with standing stocks indicated that disturbed streams receive less material and process it faster than reference streams. Benthic organic matter was collected quarterly from streams draining a 9-year-old clearcut, an 18-year-old "old-field", a 25-year-old forest, and 2 reference watersheds at Coweeta. Samples were separated into large benthic organic matter (LBOM >1 mm) and fine benthic organic matter (FBOM <1 mm) and large (>5 cm diam.) and small (1-5 cm diam.) wood. Standing stocks of LBOM were significantly higher in streams draining reference watersheds and the young 25-year-old forest than either the recent clearcut or old-field. LBOM peaked in late autumn and spring in reference streams. No seasonal patterns were observed in disturbed streams. The stream draining the 25-year-old forest had significantly higher FBOM. Standing stocks of large wood were significantly higher in the reference streams. Small wood was significantly lower in the old-field stream.

184. **Golladay, S. W.; Webster, J. R.; Benfield, E. F.; Swank, W. T. 1992.** Changes in stream stability following forest clearing as indicated by storm nutrient budgets. Archiv fur Hydrobiologie, Suppl.-Bd.90: 1-33.

This study examined changes in stream stability following forest disturbance. The index of stability used was input/output nutrient budgets, constructed for disturbed and reference streams during storms. Thus, a frequently occurring natural phenomenon (storms) was used to evaluate the effects of a large-scale disturbance (forest clearing). Nutrient budgets indicated that disturbed streams were less retentive of nitrogen and phosphorus than reference sites. Nitrogen loss averaged 57 mg/m^2 streambed/storm from disturbed and 16 mg/m^2 streambed/storm from reference sites. Phosphorus losses were 34 and 9 mg/m^2 streambed/storm from disturbed and reference streams respectively. Nitrogen and phosphorus loss was largely accounted for by export of nutrients associated with organic particles. There were no differences in input/output budgets for calcium and potassium, although disturbed streams tended to export more particulate calcium and potassium than reference sites. Changes in stream stability following forest clearing were attributable to changes in the linkage between streams and forest vegetation. Forest recovery is an autogenic process, determined by the rate of forest regrowth. Stream recovery is largely allogenic, dependent on the return of predisturbance patterns of organic inputs from the surrounding forest. Forest clearing resulted in a complex series of changes in organic inputs and processing rates which decreased the abundance of retention structures in streams. The net effect was a decrease in the ability of streams to resist the downstream transport of nutrients during storms.

185. **Grant, W. H. 1988.** Debris avalanches and the origin of first-order streams. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 103-110.

Debris avalanches and underlying joint systems are responsible for some first-order streams. The sequence for development of a stream begins with a small depression at the subsoil intersection of bedrock joints. The depression accumulates groundwater. Chemical weathering proceeds

faster in the depression, enhancing its water capacity. This process can continue indefinitely or be interrupted by a violent storm. An avalanche is initiated by hydraulic pressure through the water-saturated subsoil joint. At the storm peak, pressure is strong enough to break the adhesion between rock and water-saturated soil and saprolite. The water-inflated mass of rock and soil slides quickly down hill, leaving a chute which is the locus of a new first-order stream.

186. **Grantham, Jeremy Hummon; Velbel, Michael Anthony. 1988.** The influence of climate and topography on rock-fragment abundance in modern fluvial sands of the southern Blue Ridge Mountains, North Carolina. Journal of Sedimentary Petrology. 58(2): 219-227.

Chemical weathering influences the detrital composition of sand-size sediment derived from source areas subject to different amounts of precipitation in the Coweeta Basin. Of the grain types studied, rock fragments are most sensitive to chemical degradation; therefore, their abundance is the best indicator of cumulative weathering effects. In the Coweeta Basin, the intensity of chemical weathering is directly related to the climate via effective precipitation, whereas the duration of chemical weathering is inversely related to the topographic slope of the watershed. Therefore, soils in watersheds with low-relief and high discharge per unit area experience the most extensive chemical weathering, and sediments derived from these watersheds contain the lowest percentage of rock fragments.

187. **Greene, G. E. 1950.** Land use and trout streams. Journal of Soil and Water Conservation. 5: 125-126.

Maximum stream temperatures rose appreciably when a forested watershed at Coweeta was converted to a mountain farm. Because absence of shade can increase stream temperatures, riparian vegetation should be carefully manipulated to maintain optimum temperatures for growth and development of trout and aquatic organisms.

188. **Greenland, David; Swift, Lloyd W., Jr., eds. 1990.** Climate variability and ecosystem response: Proceedings of a long-term ecological research workshop; 1988 August 21-23; Boulder, CO. Gen. Tech. Rep. SE-65. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 90 p.

Ten papers describe studies of climate variability and ecosystem response. These studies were conducted at LTER (Long-Term Ecological Research) sites representing forest, agricultural, and aquatic ecosystems or systems in which extreme climates limit vegetational cover. An overview paper, based on discussions of the LTER Climate Committee, stresses the importance of clear terminology, temporal and spatial scales, new and more useful indices of climate, and opportunities afforded by differences and similarities among LTER sites.

189. **Greenland, David; Swift, Lloyd W., Jr. 1990.** Introduction to LTER workshop on climate variability and ecosystem response. In: Greenland, David; Swift, Lloyd W., Jr., eds. Climate variability and ecosystem response: Proceedings of a long-term ecological research workshop; 1988 August 21-23; Boulder, CO. Gen. Tech. Rep. SE-65. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 1-2.

This opening paper describes the activities of the Intersite Climate Committee, states the purpose of the Workshop, and introduces the papers included in the volume.

190. **Greenland, David; Swift, Lloyd W., Jr. 1990.** Overview of climate variability and ecosystem response. In: Greenland, David; Swift, Lloyd W., Jr., eds. Climate variability and ecosystem response: Proceedings of a long-term ecological research workshop; 1988 August 21-23; Boulder, CO. Gen. Tech. Rep. SE-65. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 85-90.

Unusual ecosystem responses are frequently driven by meteorological events. The frequency and magnitude of these events and responses can be characterized through Long-Term Ecological Research (LTER). The LTER Climate Committee identifies four issues to be considered in future investigations: (1) the need to clarify terms and definitions used in discussing climate variability, (2) the importance of recognizing the various time and space scales of climate variability and ecosystem response, (3) the need to expand data beyond dependence on traditional summaries of temperature and precipitation, and (4) the value of insights gained from examining similarities and dissimilarities among climate episodes and ecosystem responses across LTER sites.

191. **Greenland, David; Swift, Lloyd W., Jr. 1991.** Climate variability and ecosystem response: opportunities for the LTER network. Bulletin of the Ecological Society of America. 72(2): 118-126.

Unusual ecosystem responses are frequently driven by meteorological events. The frequency and magnitude of these events and responses can be characterized through Long-Term Ecological Research (LTER). The LTER Climate Committee identifies four issues to be considered in future investigations: (1) the need to clarify terms and definitions used in discussing climate variability, (2) the importance of recognizing the various time and space scales of climate variability and ecosystem response, (3) the need to expand data beyond dependence on traditional summaries of temperature and precipitation, and (4) the value of insights gained from examining similarities and dissimilarities among climate episodes and ecosystem responses across LTER sites.

192. **Grossman, Gary D.; Dowd, John F.; Crawford, Maurice. 1990.** Assemblage stability in stream fishes: a review. Environmental Management. 14(5): 661-671.

The stability of nine stream fish assemblages are represented by coefficients of variation of population size. High coefficients of variation (over 96 percent) indicate that most assemblages were quite variable. Coefficient of variation estimates were not significantly affected by: (1) years of study, (2) mean abundance, (3) familial classification, or (4) mean interval between collections. The high variability of many stream fish assemblages suggests that it may be difficult to detect the effects of anthropogenic disturbances using population data alone. Long-term studies of the ecological characteristics of undisturbed stream fish assemblages are needed to provide benchmarks to compare to disturbed systems.

193. **Grossman, G. D.; Freeman, Mary C. 1987.** Microhabitat use in a stream fish assemblage. The Journal of the Zoological Society of London. 212: 151-176.

We examined microhabitat use among fishes in a 37-m section of Coweeta Creek. Numerical abundances of species changed substantially during 17 months, although microhabitat availability did not change markedly. Analyses show two main patterns of nonrandom microhabitat use. Three species were significantly overrepresented in deep areas with low velocities and depositional substrata. Five other species all occurred in intermediate to deep microhabitats with moderate to high velocities and erosional substrata. Five of seven species exhibited seasonal variation in microhabitat utilization, whereas six species displayed size-related variation in use. Species could be assigned to either a benthic or a water column guild. Species within a guild generally could not be differentiated statistically, whereas members of different guilds were readily separable. These patterns persisted despite changes in numerical abundances. There was no evidence of either exploitation or interference competition for microhabitat; thus, spatial resources were not limiting.

194. **Grzenda, A. R.; Nicholson, H. P.; Teasley, J. I.; Patric, J. H. 1964.** DDT residues in mountain stream water as influenced by treatment practices. Journal of Economic Entomology. 57: 615-618.

DDT residues in Coweeta streams after spraying for elm spanworm by airplane in 1961 and by helicopter in 1962 are compared. DDT contamination of Coweeta Creek was negligible after precise application by helicopter in upslope and ridge areas.

195. **Gurtz, Martin E.; Wallace, J. Bruce. 1984.** Substrate-mediated response of stream invertebrates to disturbance. Ecology. 65(5): 1556-1569.

The response of aquatic invertebrates to a major watershed disturbance, clearcutting, was examined in a second-order stream. For 21 months after the start of logging, invertebrates were sampled in four substrate types: rock face, cobble riffles, pebble riffles, and sand. More taxa increased in density (compared with a nearby reference stream) in moss-covered rock face than in any other substrate; cobble riffles were next, followed by pebble riffles and sand. Conversely, the number of taxa with significant reductions in density was highest for sand substrates. Among functional groups of insects, collector-gatherers and scrapers increased, while the dominant shredder declined. The differential response of invertebrates among substrates suggests that biological stability is closely coupled with physical stability; however, moss associated with larger particles may be a factor in enhancing the biological stability.

196. **Gurtz, Martin E.; Wallace, J. Bruce. 1986.** Substratum–production relationships in net-spinning caddisflies (Trichoptera) in disturbed and undisturbed hardwood catchments. Journal of North American Benthological Society. 5(3): 230-236.

The effect of substratum on production of two species of net-spinning Trichoptera was examined in two second-order Southern Appalachian streams: Hugh White Creek, a reference stream draining an undisturbed hardwood catchment, and Big Hurricane Branch, which drains a catchment that was clearcut during the first 6 months of the study. Surber samples were collected monthly for 21 months in four common substrata in each stream: moss-covered rock face, cobble riffle, pebble riffle, and sandy reach. Both species showed distinct substratum preferences. Abundances and production were significantly higher in rock face > cobble riffle > pebble riffle > sandy reach in both streams. Differences in production between streams may be related more to geomorphic differences between streams than to effects of logging on these two species.

197. **Gurtz, Martin E.; Webster, Jackson R.; Wallace, J. Bruce. 1980.** Seston dynamics in southern Appalachian streams: effects of clear-cutting. Canadian Journal of Fisheries and Aquatic Sciences. 37: 624-631.

Suspended particulate matter was studied from July 1977 to July 1978 in two second-order streams in the Southern Appalachian Mountains. In the first stream, which drains an undisturbed hardwood forest watershed, seston concentrations fluctuated with season and with stormflows. Most organic and inorganic particles were smaller than 105 μm diameter. The second stream drains a watershed that was clearcut in early 1977. Increased levels of both organic and inorganic seston were found in the latter stream, especially beginning 1 year after clearcutting. Particles larger than 234 μm in diameter accounted for most of the increases in inorganic seston. We hypothesize that eventual recovery of the stream will be limited by the rate of recovery of the surrounding terrestrial ecosystem.

198. **Haefner, John D.; Wallace, J. Bruce. 1981.** Production and potential seston utilization by *Parapsyche cardis* and *Diplectrona modesta* (Trichoptera. Hydropsychidae) in two streams draining contrasting southern Appalachian watersheds. Environmental Entomology. 10: 433-441.

Production of *Parapsyche cardis* Ross and *Diplectrona modesta* Banks was estimated in two first-order Southern Appalachian streams. One stream drains a natural undisturbed hardwood watershed and the other a

watershed subjected to several disturbances. Since 1968 the latter has been allowed to undergo natural succession. Both hydropsychid species were univoltine in each stream. Production estimates were higher for both species in the stream draining the disturbed watershed, attributable to: (1) more suitable habitat, (2) higher densities of prey species, and (3) potentially enhanced food quality resulting from a 200-fold greater NO_3-N concentration. Estimates of animal tissue consumption are several times higher than the invertebrate drift from each watershed, suggesting that the major impact of these net spinners is on the animal fraction of the seston.

199. **Haefner, John D.; Wallace, J. Bruce. 1981.** Shifts in aquatic insect populations in a first-order southern Appalachian stream following a decade of old field succession. Canadian Journal of Fisheries and Aquatic Science. 38: 353-359.

Aquatic insect populations were sampled on two first-order Southern Appalachian streams. Grady Branch, the control stream, drains an undisturbed hardwood watershed. Sawmill Branch has undergone natural succession since 1968, from artificially maintained grassland to hardwood coppice dominated by black locust. Aquatic insect densities on Sawmill Branch were about twice those on Grady Branch, a reversal of results obtained by a similar study in 1968. It is suggested that changes in watershed vegetation influence long-term changes in aquatic insect populations, including a shift toward an allochthonous energy base.

200. **Haines, Bruce. 1983.** Forest ecosystems SO_4-S input-output discrepancies and acid rain: Are they related? Oikos. 41: 139-143.

The SO_4-S inputs exceed SO_4-S outputs in rain forests at San Carlos de Rio Negro, Amazonas, Venezuela and at La Selva, Costa Rica. Hypotheses to explain excess of inputs over outputs include (1) accumulation of S in biomass, (2) accumulation of S in soil, (3) conversion of SO_4-S to organic S compounds which leave the system in drainage water, (4) conversion of SO_4-S to volatile S compounds which leave as gases, and (5) estimation errors. Acid rain occurs at both sites. If the S were volatilized out of the forests, oxidized in the atmosphere to SO_4, (4 above) then washed out of the atmosphere by rain, the resulting quantity of H_2SO_4 would be sufficient to account for the rainfall acidity observed in the field in Costa Rica.

201. **Haines, Bruce L. 1991.** Identification and quantification of sulfur gases emitted from soils, leaf litter and live plant parts. Agriculture, Ecosystems and Environment. 34: 473-477.

Sulfur gas emission potentials can be quantified by incubating soil, leaf litter or plant parts in polypropylene centrifuge bottles, followed by analysis of accumulated head space gases with a gas chromatograph having a sulfur-specific flame photometric detector. Biological sulfur gas emissions can make a small contribution to atmospheric sulfur and to sulfuric acid rain. Sulfur gas emissions by plants are potentially significant as defenses against root rot fungi, nematodes and insects. Sulfur gas emissions which inhibit nitrification may function to conserve NH_4 in the upper soil profile.

202. **Haines, Bruce L. 1991.** Identification and quantification of sulfur gases emitted from soils, leaf litter and live plant parts. In: Crossley D. A., Jr.; Coleman, D. C.; Hendrix, P. F.; Cheng, W.; Wright, D. H.; Beare, M. H.; Edwards, C. A., eds. Modern techniques in soil ecology: Proceedings of the international workshop on modern techniques in soil ecology relevant to organic matter breakdown, nutrient cycling and soil biological processes; 1989 September 11-15; Athens, GA. New York: Elsevier: 473-477.

Reprint of 1991 paper in Agriculture, Ecosystems and Environment. 34: 473-477.

203. **Haines, B. L.; Best, G. R. 1976.** *Glomus mosseae*, endomycorrhizal with *Liquidambar styraciflua* L. seedlings retard NO_3 and NH_4 nitrogen loss from a temperate forest soil. Plant and Soil. 45: 257-261.

The influence of mycorrhizal fungus on downward movement of NH_4, NO_2, and NO_3 nitrogen in forest soil was determined by establishing combinations of soil, fungus and seedlings in plastic pipes and monitoring the nitrogen content of water percolating to two depths. Compared with controls of soil alone and of soil + seedling alone, treatments containing the mycorrhizae showed a significant reduction of NH_4-N loss from 5- and 25-cm depths and significant reduction of NO_3-N loss from the 5-cm depth. No significant effect was observed on nitrite loss.

204. **Haines, Bruce; Best, George Ronnie. 1976.** The influence of an endomycorrhizal symbiosis on nitrogen movement through soil columns under regimes of artificial throughfall and acid rain. In: Dochinger, L. S.; Seliga, T. A., eds. Proceedings, first international symposium on acid rain and the forested ecosystem; 1975 May 12-15; Columbus, OH. Gen. Tech. Rep. NE-23; Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 951-961.

The effect of artificial acid rain on nitrogen uptake by a fungus (*Glomus mosseae* (Nicol. and Gerd.) Gerd. and Trappe) endomycorrhizal with roots of sweetgum tree seedlings (*Liquidambar styraciflua* L.) was investigated by applying three kinds of test solutions to the surface of soil profiles planted with five combinations of sweetgum seedlings and fungus. When artificial Eastern United States acid rainfall was used to acidify the top 5 cm of soil to a soil solution pH of 2.0, NO_3-N concentrations were unaffected by soil-tree fungus treatments while ammonia appeared to be excluded from soil exchange sites, apparently by H ions. Ammonia uptake by mycorrhizal roots was not detectable, thus acid rain may promote leaching from NH_4-N from soil profiles.

205. **Haines, Bruce; Black, Marilyn; Bayer, Charlene. 1989.** Sulfur emissions from roots of the rain forest tree *Stryphnodendron excelsum*. In: Saltzman, Eric S.; Cooper, William J., eds. Biogenic sulfur in the

environment; ACS Symp. Ser. 393; 194th meeting of the American Chemical Society, Division of Environmental Chemistry; 1987 August 30-September 4; New Orleans. Washington, DC: American Chemical Society: 58-69.

Roots of *Stryphnodendron excelsum* trees in a lowland rain forest in eastern Costa Rica emit sulfur gases. Extrapolated annual estimates of emissions, based on *S. excelsum* tree density, are on the order of 0.29 kg S/ha/yr. At the ecosystem level, this flux is too small to account for the 11 kg S/ha/yr SO_4-S input-output discrepancy and acid rain reported earlier. At the physiological level, emission of CS_2 is stimulated by disturbance to the roots of *S. excelsum*. Considering the known toxicity of CS_2 to nematodes, root rot fungi, insects, and nitrifying bacteria, we suggest that CS_2 emission may, at the community level, be a defensive mechanism against root predators and pathogens, and a nitrogen conserving mechanism.

206. **Haines, B.; Black, M.; Fail, J., Jr.; McHargue, L.; Howell, G. 1987.** Potential sulphur gas emissions from a tropical rainforest and a Southern Appalachian deciduous forest. In: Hutchinson, T. C.; Meema, K. M., eds. Effects of atmospheric pollutants on forests, wetlands, and agricultural ecosystems. NATO ASI Series G: Ecological Sciences, vol. 16. Berlin Heidelberg: Springer-Verlag: 559-610.

Potential emission rates of reduced sulphur gases were estimated for a tropical rainforest and a Southern Appalachian deciduous forest. Emissions were sampled by cuvettes on the forest floor, by incubating samples of living plant material, leaf litter, and soil in closed containers, and by pumping air from around plant canopies. Quantifying the contribution of natural sulphur emissions to the atmospheric sulphur burden and to acid rain on a global scale is hampered by the great diversity of habitats, the temporal and spatial variability of sulphur emissions within habitats, and by analytical problems. Potential sulphur emission rates were low. Some rainforest legumes emitted ethyl mercaptan and carbon disulphide from seeds, wood samples, roots, or leaves. These emissions, which are new to plant physiology research, may have community implications, but as point sources in a rainforest are a sampling problem for ecosystem level studies. H_2S emission from plant canopies in the rainforest and at Coweeta was not detected.

207. **Haines, Bruce; Chapman, James; Monk, Carl D. 1985.** Rates of mineral element leaching from leaves of nine plant species from a Southern Appalachian forest succession subjected to simulated acid rain. Bulletin of the Torrey Botanical Club. 112(3): 258-264.

Rates of mineral element leaching from plants subjected to simulated acid rain were determined for a forest succession including early successional herbs and a shrub-tree and six successional tree species. Simulated rain consisted of pH values of 5.5, 4.5, 3.5, and 2.5. Solutions were applied through a raindrop simulator at 0.9 cm/hr for 10 periods of 1 hour. each. Leachate from the leaves was analyzed for NH_4-N, NO_3-N, K, Ca, Mg, and P. Rates of leaching ranged from 0.006 to 11.3 mg of element/10 dm^2/hr. There were highly significant differences in leaching rates among species but no significant differences among pH treatments. Highest leaching rates occurred in the herbs. The absence of a pH effect on leaching rates is consistent with the absence of evidence of acid rain damage to the leaves of the plants tested.

208. **Haines, Bruce; Stefani, Marcia; Hendrix, Floyd. 1980.** Acid rain: threshold of leaf damage in eight plant species from a southern Appalachian forest succession. Water, Air and Soil Pollution. 14: 403-407.

Eight plant species were subjected to artificial acid rains of pH 2.5, 2.0, 1.5, 1.0, and 0.5 in order to determine the threshold for and symptoms of damage. The plants were *Erechtites*, *Robinia*, *Pinus*, *Quercus*, *Carya*, *Liriodendron*, *Acer* and *Cornus* from the Coweeta Hydrologic Laboratory. Droplets of pH 2.0 produced brown/necrotic spots on all species except *Pinus*, while droplets of pH 1.0 produced necroses on leaves of all species examined. The size of necrotic spots increased with increasing acidity. Results of this study suggest that a tenfold increase in acidity from pH 3.2 to 2.2 in a single spring or summer storm could bring damage or death to mature leaves of dominant flowering plants in the Southern Appalachians.

209. **Haines, B. L.; Swank, W. T. 1988.** Acid precipitation effects on forest processes. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 359-366.

Acid rain can displace essential elements from plant leaves and soil, and it can inhibit element uptake by plants. These processes of leaching and inhibition of uptake have the potential to disrupt the cycling of mineral elements upon which forest production is dependent. This paper reviews results of experiments to determine potential effects of acid rain on forest processes at Coweeta. Plant growth and the integration of above- and belowground processes are explored in relation to the interacting stresses of acid rain, oxidants, and other environmental variables.

210. **Haines, Bruce; Waide, Jack B. 1980.** Predicting potential impacts of acid rain on elemental cycling in a southern Appalachian deciduous forest at Coweeta. In: Hutchinson, T. C.; Havas, M., eds. Effects of acid precipitation in terrestrial ecosystems: Proceedings of the symposium; 1978 May 21-27; Toronto. New York: Plenum Publications; North Atlantic Treaty Organization, Scientific Affairs Division: 335-340.

Experimental efforts to characterize the responses of plant leaves, plant roots and soils to different regimes of acid rain are described. The goal is to integrate response data into ecosystem models in order to make predictive simulations of potential long-term responses of southeastern forests to acid rain regimes differing in intensity and in duration as well as ecosystem recovery following cessation of low pH rainfall.

211. **Haines, B. L.; Waide, J. B.; Todd, R. L. 1982.** Soil solution nutrient concentrations sampled with tension and zero-tension lysimeters: report of discrepancies. Soil Science Society of America Journal. 46: 658-661.

Four lysimeters were installed at each of 16 randomly designated locations. At each location, first at the litter-soil interface and again 30 cm beneath the litter-soil interface, one tension and one zero-tension lysimeter were installed side by side. Samples for 13 time intervals over a 15-month period were analyzed for water volume, H, NH_4, K, Na, Ca, Mg, and NO_3, Cl, SO_4, H_2PO_4, and dissolved silica. Estimates of soil solution composition and water flow differed according to lysimeter type and sampling depth. A testable hypothesis is advanced to account for these observed discrepancies.

212. **Hairston, Nelson G. 1973.** Ecology, selection and systematics. Cambridge, MA: Museum of Comparative Zoology; Breviora. 414. 21 p.

Three different kinds of ecological relationships between newly separated species of salamanders are examined, with the aim of establishing their expected effects on the systematic differences between the species involved. In cases of slight difference between the habitats of two products of recent speciation, selection can be expected to favor specific competitive mechanisms, but taxonomic differences would be expected to be slight, and examples of hybrid superiority would be common. Where the habitats of the two species are markedly different, as along a steep ecological gradient, adaptation to the different places will result in species that become broadly overlapping in habitat, and taxonomically different in many clearly adaptive characters. Although this latter process leads to species with somewhat different food habits, it would not lead to food specialization.

213. **Hairston, Nelson G. 1980.** Species packing in the salamander genus Desmognathus: what are the interspecific interactions involved? The American Naturalist. 115(3): 354-366.

This paper presents evidence that questions previous interpretations and indicates that predation in and near streams has been more important than competition as the significant force in determining the evolution of the genus and the present structure of the community. The evidence consists of the size relationships, which are the reverse of what would be expected if competition had required increasing efficiency, the relative abundance of salamander predators in aquatic and terrestrial environments, and the failure of a majority of predictions about habitat shifts and size relationships when the predictions are based on the assumption of interspecific competition.

214. **Hairston, Nelson G., Sr. 1986.** Species packing in *Desmognathus* salamanders: experimental demonstration of predation and competition. The American Naturalist. 127(3): 266-291.

Salamanders have provided excellent material for ecological experiments. Long-lived animals with unusually stable populations, they conform to the implied assumptions embedded in theories of community organization and of evolution under the influence of interspecific interactions. Many species are abundant enough to provide ample material for experiments, and in some areas, especially the Southern Appalachians, multispecies associations among the family Plethodontidae are available for testing hypotheses about the organization of communities and the coevolution of their constituent species.

215. **Hairston, Nelson G., Sr.; Wiley, R. Haven; Smith, Charles K.; Kneidel, Kenneth A. 1992.** The dynamics of two hybrid zones in Appalachian salamanders of the genus *Plethodon*. Evolution. 46(4): 930-938.

Two zones of intergradation between populations of *Plethodon* have been studied for 18 and 20 years, respectively. The data consist of systematic scores of colors, made at least twice annually. Near Heintooga Overlook in the Balsam Mountains (Great Smoky Mountains National Park), the salamanders' cheeks are gray. Proceeding north toward the Smokies, there is increasing frequency and intensity of red color at 2, 4, and 6 miles. There has been no change in the scores at any location. The width of the zone and our failure to detect any change can be explained by assuming neutrality of the character and random diffusion during the probable time since contact between the two intergrading forms, which most likely took place after the Hypsithermal Interval, 8000-5000 BP. At Coweeta Hydrologic Laboratory in the Nantahala Mountains, *Plethodon jordani* and *P. glutinosus* hybridize at intermediate elevations. The lateral white spots of *glutinosus* decrease and the red on the legs of *jordani* increases with elevation from 685 m to 1052 m. At the higher elevation, the proportion of animals scored as "pure" *jordani* declined significantly from 1974 to 1990, an indication that the hybrid zone is spreading upward. The rate of spread is too great to be explained by random diffusion, so selection for *glutinosus* characters is the best explanation. The rate of spread of the hybrid zone indicates that hybridization began 60 to 65 years ago, at the end of the time of intense timbering. Such human disturbances have caused hybridization in other organisms.

216. **Hale, D. D.; Fitzgerald, J. W. 1990.** Generation of sulphate from cysteine in forest soil and litter. Soil Biology and Biochemistry. 22(3): 427-429.

We have investigated cysteine transformation in forest floor layers and soil and have determined the effects of pH, substrate concentration and antimicrobial agents on the mineralization and immobilization of this amino acid.

217. **Hanson, P. J.; Taylor, G. E., Jr.; Vose, J. 1992.** Experimental laboratory measurements of reactive N gas deposition to forest landscape surfaces: biological and environmental controls. In: Johnson, Dale W.; Lindberg, Steven E., eds. Atmospheric deposition and forest nutrient cycling: a synthesis of the Integrated Forest Study. Ecological Studies, vol. 91. New York: Springer-Verlag: 166-177, 207-213.

Laboratory and field studies were conducted to determine the deposition of NO_2 and HNO_3 to woody plants. Deposition of NO_2 to foliage was linearly related to stomatal conductance across a range of hardwood and conifer species, emphasizing the importance of internal deposition. Deposition rates were as high as 5 nmol/m^2/s. In contrast, HNO_3 exhibited substantial deposition to external leaf surfaces, although some internal deposition also occurred. Internal deposition rates ranged from 5 to 53 nmol/g/s. Extrapolating deposition rates to forest stands resulted in estimates of NO_2 deposition ranging from 11 to 200 mol/ha/yr and HNO_3 deposition from 25 to 213 mol/ha/yr. The wide variation in deposition values was related to differences in leaf area index and ambient NO_2 and HNO_3 concentrations.

218. **Hargrove, William W. 1986.** An annotated species list of insect herbivores commonly associated with black locust, *Robinia pseudoacacia*, in the Southern Appalachians. Entomological News. 97(1): 36-40.

An annotated species list is presented as an aid to identification of phytophagous insects found on black locust, *Robinia pseudoacacia*, in the Southern Appalachians. The list, containing 75 species, is annotated regarding host preference, presence in Southern Appalachians, abundance, and host specificity.

219. **Hargrove, William W. 1988.** A photographic technique for tracking herbivory on individual leaves through time. Ecological Entomology. 13: 359-363.

Accurate measurement of leaf area removed (LAR) by chewing insect herbivores is used to evaluate progress in insect control, plant breeding, and genetic screening and engineering programs, and to assess impacts of herbivores on ecosystem function. End-of-season estimates of LAR may underestimate herbivory because of hole growth with leaf expansion and consumption of entire leaves. This report describes a method using photographic proof paper for following herbivory through time, yielding more accurate estimates and indicating the seasonal dynamics of herbivory.

220. **Hargrove, William W.; Crossley, D. A., Jr. 1988.** Video digitizer for the rapid measurement of leaf area lost to herbivorous insects. Annals of the Entomological Society of America. 81(4): 593-598.

An IBM PC or compatible microcomputer equipped with a Tekmatic Systems Video Van Gogh digitizer card can be interfaced with a standard video camera for rapidly measuring the percentage of leaf area lost (LAL) to herbivorous insects. The system digitizes a video image of a reconstructed leaf and displays the amount of LAL in about 20 seconds. The video digitizer simultaneously measures area removed from, and area remaining in, the leaf without tracing of these areas by the operator, greatly increasing the number of leaves that can be measured. Digitized measurements are saved to a sequential ASCII data file compatible with database, spreadsheet, and word processor programs. The video digitizer software allows two video camera work stations to be supported by a single computer. Software for the video digitizer is in the public domain and can be obtained from the authors.

221. **Hargrove, W. W.; Crossley, D. A., Jr.; Seastedt, T. R. 1984.** Shifts in insect herbivory in the canopy of black locust, *Robinia pseudoacacia*, after fertilization. Oikos. 43: 322-328.

Black locust trees fertilized with N, P, and K initially incurred higher losses to chewing insects, but subsequently gained some protection from herbivory. This protection consisted of two distinct tactics: (1) a tolerance response, in which greater photosynthetic area was produced, and (2) a resistance response, in which insect preference shifted to foliage of nonfertilized trees. Consumption damage accrued in the foliage of control trees in a linear fashion throughout the season. Relative concentrations of five major macronutrients were statistically the same or greater in foliage of fertilized trees than in controls from mid-June through August. A small secondary leaf flush was observed exclusively in fertilized trees.

222. **Hargrove, W. W.; O'Hop, J. R., Jr. 1988.** A computer algorithm to estimate leaf area removal (LAR) by insects. Laboratory Microcomputer. 7(1): 36-40.

A computer algorithm is described which can be used with a magnetic planimeter board to produce a rapid and accurate digital planimeter. A version for the measurement of percentage of leaf area removal by chewing phytophagous insects is given, although the algorithm has wide ecological applicability and is compatible with many small computer systems. An area algorithm using polar rather than rectangular coordinates economizes on the storage of intermediate points, allowing measurement of closed areas of any size or shape. Correction routines allow for removal of errors and preservation of statistical intermediates. Data collection, transformation, storage and initial statistical analysis are performed during the measurement step. Estimation error is less than 1.2 percent when measuring actual areas of 25 cm^2 or less.

223. **Harris, W. F.; Santantonio, Dan; McGinty, D. 1980.** The dynamic belowground ecosystem. In: Waring, Richard H., ed. Forests: fresh perspectives from ecosystem analysis: Proceedings of the 40th annual biology colloquium; 1979 April 27-28; Corvallis, OR. Corvallis, OR: Oregon State Press: 119-129.

The belowground ecosystem, especially the autotrophic root component, plays an important role in the structure and function of forest ecosystems. This paper discusses the seasonal accumulation and turnover of root organic matter, the significance of root dynamics to element inputs to soil and element cycling, and the significance of root sloughing to the forest energy balance.

224. **Harshbarger, Thomas J. 1975.** Research in aquatic habitats at Southeastern Station. In: Symposium on trout habitat research and management: Proceedings; 1974 September 5-6; Cullowhee, NC. Boone, NC: Appalachian Consortium Press: 102-106.

Research is urgently needed to restore, maintain, or improve approximately 20,000 miles of trout stream in the Southern Appalachian Mountains. Studies conducted at Coweeta show that land management practices change the quantity, quality, and stability of water flowing from forest land and the stream biota. This paper describes research approaches, current studies, and plans for future work in aquatic habitat research by the Southeastern Forest Experiment Station.

225. **Harshbarger, Thomas J. 1978.** Factors affecting regional trout stream productivity. In: Proceedings of the southeastern trout resource: ecology and management symposium; 1975 October 24-25; Blacksburg, VA. Blacksburg, VA: Virginia Polytechnic Institute and State University: 11-27.

This paper reviews effects of abiotic factors such as temperature, stream velocity, discharge, and dissolved ions on distribution and abundance of trout, independent of population density. Some factors, such as temperature and dissolved ions, act in a fairly constant manner, but others, such as discharge, are erratic in occurrence and cause major fluctuations in production levels. More information is needed to fully assess the effects of climate and physical environment on wild trout.

226. **Harshbarger, Thomas J. 1979.** Scraping improves silver nitrate brands on trout. Progressive Fish-Culturist. 41: 209.

A device for scraping mucosal material and scales from fish prior to branding with silver nitrate is described. Improved brands are obtained using this technique.

227. **Harshbarger, T. J. 1980.** Effects of changed structural habitat on trout and invertebrate populations. In: Proceedings of the trout stream habitat improvement workshop; 1980 November 3-6; Asheville, NC. Atlanta, GA: U.S. Department of Agriculture, Forest Service: 123-126.

Channel constructions and over logs placed in a three-order stream in North Carolina increased depth and velocity but decreased surface area of water. The number of cover units increased, but their size decreased. The net effect was a significant reduction in standing crop of wild brown and rainbow trout. Streamside debris supported high invertebrate biomass (fish food), and carrying capacity of streams might benefit from installing devices to trap and hold organic debris.

228. **Harshbarger, Thomas J. 1984.** Fish census. In: Wenger, Karl F., ed. Forestry handbook. 2d ed. New York: John Wiley & Sons: 706-708.

This portion of the section on forest wildlife and fish management briefly describes for the land manager various ways of conducting a fish census in streams or lakes, including methods using nets, electrofishing, toxicants and creel census.

229. **Harshbarger, Thomas J. 1984.** Living trout mean living water. Katuah. 4: 3, 22.

This nontechnical survey of the impacts of land use upon mountain trout waters was published in newspaper format.

230. **Harshbarger, T. J.; Bhattacharyya, H. 1981.** An application of factor analysis in an aquatic habitat study. In: Capen, D. E., ed. The use of multivariate statistics in studies of wildlife habitat. Gen. Tech. Rep. RM-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest Experiment Station: 180-184.

In 5 small, high-gradient trout streams in western North Carolina, 18 cover variables were related to standing crop biomass of wild brook trout (*Salvelinus fontinalis*), rainbow trout (*Salmo gairdneri*) and brown trout (*Salmo trutta*). Factor analysis showed that only a few factors or variables were needed to explain relations between variables in the observed set. Key cover factors were area in debris; turbulent water; vegetation in and over stream; and overhanging banks. Resolutions obtained were used to explore relationships between standing crop of trout and age of fish.

231. **Harshbarger, T. J.; Perkins, C. J.; Martin, R. E. 1975.** Legume response unrelated to fuel moisture at time of burning. Journal of Range Management. 28: 70-71.

The response of sensitive partridgepea and other legumes was unrelated to moisture content of fuels at the time a slash pine stand was burned.

232. **Harshbarger, Thomas J.; Porter, Pamela E. 1979.** Survival of brown trout eggs: two planting techniques compared. Progressive Fish-Culturist. 41: 206-209.

This paper compares survival of eggs, embryos, and swim-up fry of brown trout (*Salmo trutta*) in direct intragravel plants and in Vibert boxes. Egg mortality increased disproportionately in Vibert boxes after 4 weeks until time of hatching. Direct intragravel plants yielded the highest survival to the swim-up stage.

233. **Harshbarger, Thomas J.; Porter, Pamela E. 1982.** Effects of a dam and sewage outflow on a small oligotrophic stream in the Southern Appalachians. Res. Note SE-308. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 10 p.

Treated sewage added to a Southern Appalachian trout stream increased bacterial production by 476 percent, periphyton production by 191 percent, and the number of benthic macroinvertebrates by 441 percent; biomass of fish decreased 56 percent. Downstream 300 m from the sewage outflow, fish biomass was significantly greater than in upstream sections. The dam influenced fish distribution and upstream migration and the abundance of filter-feeding caddisflies and midges.

234. **Harshbarger, T. J.; Porter, P. E. 1982.** Embryo survival and fry emergence from artificially planted trout eggs: two techniques compared. North American Journal of Fisheries Management. 2: 84-89.

Survival of larval trout through the swim-up stage was determined for eyed eggs of brown trout (*Salmo trutta*) planted both in the streambed and in Whitlock Vibert boxes. Direct plants produced 2 times more sac fry than box plants and 3.5 times more swim-up fry. Sediment deposition was approximately 100 percent greater in first- and second-order streams than in third-order streams, and sediments accumulated disproportionately in box plants. This seemed to account for survival differences between planting techniques and among stream orders.

235. **Hassler, W. W.; Tebo, L. B., Jr. 1958.** Fish management investigations on trout streams. Raleigh, NC: North Carolina Wildlife Resources Commission, Fish Division; completion report; project F-4-R. 118 p.

This is a report of the cooperative Dingell-Johnson investigation at Coweeta Hydrologic Laboratory. The report includes an extensive description of bottom fauna and describes the effects of erosion debris and riparian cuttings upon fish life.

236. **Hatcher, Robert D., Jr. 1979.** The Coweeta Group and Coweeta syncline: major features of the North Carolina - Georgia Blue Ridge. Southeastern Geology. 21(1): 17-29.

The name Coweeta Group is proposed for a group of metasedimentary and possible metaigneous rocks which occur in the east-central Blue Ridge of North Carolina and Georgia and overlie the rocks of the Tallulah Falls Formation. The group is composed of three formations. The oldest is the Persimmon Creek Gneiss. This is overlain by the Coleman River Formation, then the Ridgepole Mountain Formation. The age of the Coweeta Group is uncertain. The Coweeta syncline results from a history of polyphase deformation. It appears to be overturned toward the east, and the west limb is cut off by the Shope Fork fault.

237. **Hatcher, R. D., Jr. 1988.** Bedrock geology and regional geologic setting of Coweeta Hydrologic Laboratory in the eastern Blue Ridge. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 81-92.

The Appalachian Highlands represent the last remnant of a more extensive mountain chain, which at one time was as lofty as many of the modern, less eroded chains of the world such as the Alps, Andes, and North American Cordillera. This chapter discusses the bedrock geology of Coweeta Hydrologic Laboratory and places it into the context of Blue Ridge geology. Control of topography by structure and the nature of the Quaternary deposits is discussed.

238. **Helvey, Junior D. 1964.** Rainfall interception by hardwood forest litter in the Southern Appalachians. Res. Pap. SE-8. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 9 p.

Moisture interception by hardwood litter was measured during 1961 and 1962. The maximum field water content–water retained against drainage–averaged 215 percent of ovendry weight. About 1 inch of throughfall was required to wet the litter to this maximum. The amount of water evaporated per month from litter was greater during the dormant season. Interception loss during 1962 was about 2.2 inches and the long-term average is estimated to be about 3 inches.

239. **Helvey, J. D. 1967.** Interception by eastern white pine. Water Resources Research. 3: 723-729.

Measurements taken in a 10-, a 35-, and a 60-year-old stand of eastern white pine in the Southern Appalachians of western North Carolina were used to derive regression equations for estimating throughfall, stemflow, and the sum of throughfall and stemflow from measurements of gross rainfall. Equations for total interception loss were derived and used to predict total seasonal interception loss (I) from measurements of total seasonal rainfall (P) and number of storms (N). For the 10-year-old stand, $I = 0.05(N) + 0.08(P)$; for the 35-year-old stand, $I = 0.05(N) + 0.12(P)$; and for the 60-year-old stand, $I = 0.06(N) + 0.18(P)$. Total interception loss in white pine increased with stand age, and total loss from all pine stands studied exceeded losses calculated for mature hardwoods.

240. **Helvey, J. D. 1968.** Reply to Editor Langbein in answer to Professor Miller's comments on "Interception by Eastern White Pine." Water Resources Research. 4: 455-456.

This is a rebuttal to comments by Professor Miller on the article "Interception by Eastern White Pine."

241. **Helvey, J. D. 1970.** Interception of rain. In: Toebes, C.; Ouryvaev, V., eds. Representative and experimental basins; an international guide for research and practice. Vol. 4. Haarlem: Henkes-Holland, UNESCO: 89-93.

Some guidelines are presented for designing studies of rainfall interception in forest vegetation. Methods are presented for sampling gross rainfall, throughfall, stemflow, and litter interception loss. The necessary information is presented for determining a first approximation of the sampling intensity needed to achieve a desired level of accuracy.

242. **Helvey, J. D. 1971.** A summary of rainfall interception by certain conifers of North America. In: Monke, E. J., ed. Biological effects in the hydrological cycle-terrestrial phase: Proceedings of the 3d international seminar for hydrology professors; 1971 July 18-30; West Lafayette, IN. West Lafayette, IN: Purdue University, Department of Agricultural Engineering, Agricultural Experiment Station: 103-113.

Conifer interception data were compiled from many sources and generalized equations derived for canopy interception, throughfall, and stemflow. Equations for six conifers are compared with an earlier derived one for mixed deciduous forest. Surface area index correlates with differences in interception loss between dense-canopy species such as spruce, fir, and hemlock and more-open canopies of the pines.

243. **Helvey, J. D.; Hewlett, J. D. 1962.** The annual range of soil moisture under high rainfall in the Southern Appalachians. Journal of Forestry. 60: 485-486.

Observations of soil moisture at Coweeta suggest that forest vegetation at this Laboratory rarely, if ever, suffers true drought. Seasonal changes in soil moisture were strongly correlated with changes in streamflow.

244. **Helvey, J. D.; Hewlett, J. D.; Douglass, J. E. 1972.** Predicting soil moisture in the Southern Appalachians. Proceedings, Soil Science Society of America. 36: 954-959.

Soil moisture was measured for 3.5 years on forested slopes in the mountains of western North Carolina to develop equations for predicting soil moisture. Predictors were precipitation, sand content, moisture, retention at 1-bar suction, position on slope, and season. Moisture changes in surface layers were correlated best with rainfall on days immediately preceding. Changes in deeper layers were better correlated with rainfall during previous weeks. Equations developed account for about 88 percent of the variation in soil moisture.

245. **Helvey, J. D.; Patric, J. H. 1965.** Canopy and litter interception of rainfall by hardwoods of Eastern United States. Water Resources Research. 1: 193-206.

Results from all available studies of rainfall interception by hardwoods of the Eastern United States vary over a small range. Data from past studies were used to develop regression equations describing the relation between gross rainfall, throughfall, and stemflow for eastern hardwood forests during the growing and dormant seasons.

246. **Helvey, J. D.; Patric, J. H. 1966.** Design criteria for interception studies. In: Design of hydrological networks: Symposium. International Association of Scientific Hydrology; 1965 June 15-22; Quebec, Canada. Publ. 67. Washington, DC: International Association of Scientific Hydrology: 131-137. Vol. 1.

This report, gleaned from over 50 studies, defines variability of interception parameters and provides sampling designs for obtaining estimates to selected levels of probability for each parameter mean. A new method for estimating stemflow is outlined which greatly reduces variability inherent in the traditional single-tree method. These sampling and analytical methods will help ensure that results of different studies are comparable.

247. **Helvey, J. D.; Patric, J. H. 1988.** Research on interception losses and soil moisture relationships. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 129-137.

This chapter summarizes a mass of interception and soil moisture data and reviews conclusions of Coweeta research. Consolidation of interception results from studies at many eastern sites identified a commonality that has been invaluable in obtaining widely applicable forest interception estimates. Studies of soil moisture content and flux played a key role in development of the variable source area concept and interpretation of water yield results. Both areas of knowledge contribute to advances in studies of nutrient cycling and ecosystem responses.

248. **Henderson, Gray S.; Swank, Wayne T.; Hornbeck, James W. 1980.** Impacts of sulfur deposition on the quality of water from forested watersheds. In: Shriner, D. S.; Richmond, C. R.; Lindberg, S. E., eds. Potential environmental and health consequences of atmospheric sulfur deposition: Proceedings of the 2d life science symposium; 1979 October 14-18; Gatlinburg, TN. Ann Arbor, MI: Ann Arbor Science Publications, Incorporated: 431-441.

Observed stream discharge of NO_3-N was used to calculate H-ion production due to accelerated nitrification after forest harvest on five experimental watersheds. The value for H production was combined with observed cation discharge to estimate cation release ratios from the soil exchange complex. These ratios were then used to estimate potential increases in watershed discharge of cations if precipitation acidity were to change from pH 4.3 to pH 4.0, 3.5, or 3.0. The potential increases in annual Ca, Mg, K, and Na discharge were <0.5 kg/ha at pH 4.0 and <2.5 kg/ha at pH 3.5, increases which would be difficult to detect among natural variations in stream water chemistry. Calculations for precipitation at pH 3.0 suggest a potential increase in cation discharge as great as 8.5 kg/ha for individual elements.

249. **Henderson, G. S.; Swank, W. T.; Waide, J. B.; Grier, C. C. 1978.** Nutrient budgets of Appalachian and Cascade region watersheds: a comparison. Forest Science. 24: 385-397.

Precipitation inputs and streamflow outputs of nitrogen, calcium, potassium, magnesium, and sodium were compared for two deciduous forest watersheds and a coniferous forest watershed. While nitrogen inputs varied by nearly tenfold among the watersheds, ammonium and nitrate discharge in streamflow was uniformly small resulting in net accumulation within all three ecosystems. In contrast, cation discharge was more variable among the watersheds than cation input and was strongly related to the bedrock of each watershed. The internal distribution and cycling of nitrogen, potassium, and calcium within each of the three watershed ecosystems were also compared. There were interpretable differences between nutrient cycling patterns in the coniferous and

deciduous forests. Overall, however, all three ecosystems were effectively retaining and recycling these nutrients.

250. **Hermann, H. R.; Mullen, M.; Wallace, J. B. 1975.** Suction disc in *Blepharia separata* Alexander. Journal of the Georgia Entomological Society. 10: 145-150.

Suction discs on blepharocerid larvae occur on six segments of the head, thorax and abdomen. All of the structures associated with each disc are below the ventral longitudinal muscle of the body and hence belong to the sternal region. Each disc can be broken down into a zone of membranous cushion, a zone of inverted filaments, a zone of tactile setae and a zone of support. Each zone has a specific function and every zone is important in the suction mechanism. A sternal gland secretes a substance that flows into the zone of inverted filaments. Strong dilator muscle groups are responsible for indefinite suction and release mechanisms.

251. **Hershfield, David M. 1965.** On spacing of raingages. In: Design of hydrological networks: Symposium, 1965 June 15-22; Quebec, Canada. Publication 67. Gentbrugge, Belgium: International Association of Scientific Hydrology: 72-81.

Rainfall data for 15 storms from each of 15 watersheds with a total of 400 rain gages were used to obtain relationships fundamental to the spacing of rain gages for hydrologic investigations. The product-moment correlation coefficient (r) was computed for each combination of two rain gages in a watershed. Isocorrelation lines around a key gage in each watershed generally exhibit a nonisotrophic pattern. The size and shape of area enveloped by the $r = 0.9$ isoline around different key gages in the same watershed suggests that each gage represents a different-size rainfall area. A relationship is presented for obtaining the distance between rain gages for an arbitrary standard ($r = 0.9$) as a function of two readily available climatic parameters.

252. **Hertzler, R. A. 1938.** Determination of a formula for the 120° V-notch weir. Civil Engineering 8: 756-757.

Design of a 120° V-notch sharp-crested weir for accurate measurement of flows up to 26 second-feet is described. For a 2-foot head, the 120° notch has 1.73 times the capacity of a 90° notch and slightly greater capacity than the 2.6-foot rectangular weir. Weir blades were constructed of 3.5- by 3.5-inch structural angle iron. The discharge formula was $Q = 4.43\ H^{2.449}$, where Q = discharge in second-feet and H = observed head on weir.

253. **Hertzler, R. A. 1939.** Engineering aspects of the influence of forests on mountain streams. Civil Engineering. 9: 487-489.

This article discusses the objectives of the hydrologic research program at Coweeta, Bent Creek and Copper Basin, the weir instrumentation used, and typical early analyses and applications. The application of Horton's infiltration theory to forest lands which have high infiltration rates is questioned. Unit graph analyses of runoff showed that peak percentages of runoff were inversely related to basin area, that basal lengths of the distribution graphs were directly related to drainage area, and that the effects of vegetative cover were reflected in both peak percentages and width of the distribution graphs. A quantitative ranking of peak discharge from four cover types is presented.

254. **Hewlett, John D. 1957.** Coweeta Hydrologic Laboratory. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 8 p.

This booklet describes research conducted at Coweeta to develop practical methods of managing forest land for maximum timber production, while providing for flood control and maintaining the quality and quantity of water needed for industrial, municipal, and agricultural uses. Results of watershed clearings, mountain farming, woodland grazing, and proper logging procedures are illustrated.

255. **Hewlett, John D. 1958.** Pine and hardwood forest water yield. Journal of Soil and Water Conservation. 13: 106-109.

This paper discusses the theoretical concepts and experimental results which indicate that conifers use more water than hardwoods. Two catchment studies of the effect on water yield of converting hardwoods to white pine are described.

256. **Hewlett, John D. 1961.** Response of fescue to natural moisture gradient on an artificial slope. Asheville, NC: Res. Notes 152. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 2 p.

Minor changes in soil moisture stress on well-watered natural slopes may, in part, account for observed reductions in form and vigor of plants with increasing elevation.

257. **Hewlett, John D. 1961.** Soil moisture as a source of base flow from steep mountain watersheds. Stn. Pap. 132. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

Model studies of unsaturated flow in sloping soil columns show that unsaturated flow of water is an important source of base flow in mountain streams.

258. **Hewlett, J. D. 1964.** Letter to editor on article "Groundwater: Definition" by H. E. Thomas and L. B. Leopold. Science. 144(3625): 1407-1408.

This letter questions the definition of groundwater used in the article.

259. **Hewlett, John D. 1964.** Research in hydrology of forested headwaters of the Coweeta Hydrologic Laboratory. In: Transactions, 29th North American wildlife and natural resources conference; 1964 March 9-11; Las Vegas, NV. Washington, DC: Wildlife Management Institute: 103-112.

The author provides background and review of research in forest hydrology at Coweeta and plans for future staffing and research at the Laboratory.

260. **Hewlett, John D. 1964.** Water or forest - can we have all we need of both? Frontiers of Plant Science. 17: 2-3.

The author outlines an experiment with a transpiration inhibitor and cites benefits possible if this or related tests succeed.

261. **Hewlett, John D. 1966.** Will water demand dominate forest management in the East? In: Proceedings of the Society of American Foresters meeting; 1966 September 12-15; Seattle, WA. Washington, DC: Society of American Foresters: 154-158.

The author discusses results of watershed management studies at Wagon Wheel Gap and Coweeta. He raises questions about forest management solely for the purpose of water regulation and points to an alternative of intensive management for water, timber, wildlife, and recreation, using Coweeta's Watershed 28 as a successful example.

262. **Hewlett, J. D.; Cunningham, G. B.; Troendle, C. A. 1977.** Predicting stormflow and peakflow from small basins in humid areas by the R-index method. Water Resources Research. 13: 231-253.

A nonlinear equation was fitted to 468 stormflows on 11 forested basins from New Hampshire to South Carolina, providing an equation for use on forest and wild lands in humid regions. Stormflow (Q) is a function of R, P and I, where R, the average storage capacity index, is the mean value of Q/P. P is storm rainfall, and I is the initial flow rate. S.E. is 0.3 inch of stormflow. Peakflow was similarly estimated (S.E. 26 $ft^3/sec/mi^2$). The R-index method is proposed as a practical tool in wild-land management. When tested against the runoff curve method on four independent basins, predictions by the R-index method were considerably more accurate.

263. **Hewlett, John D.; Douglass, James E. 1961.** A method for calculating error of soil moisture volumes in gravimetric sampling. Forest Science. 7: 265-272.

A method for calculating error of soil moisture volumes in gravimetric sampling is presented. Limitations in sampling soil density and percentage of moisture to determine inches of water render the gravimetric method a poor tool for hydrologic research.

264. **Hewlett, John D.; Douglass, James E. 1968.** Blending forest uses. Res. Pap. SE-37. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 15 p.

Compatibility of forest management practices on a 360-acre Southern Appalachian watershed, along with conflicts among uses, is examined in this unique experiment to determine the feasibility of intensive management for wood, water, wildlife, and recreation. An efficient and stable access system is stressed, and the effect of various woods practices on the four basic resources is rated. Increases are shown in water yield, game forage, quality timber growth, and general use of the area, and some unresolved conflicts among uses of the forest are revealed.

265. **Hewlett, John D.; Douglass, James E.; Clutter, Jerome L. 1964.** Instrumental and soil moisture variance using the neutron-scattering method. Soil Science. 97: 19-24.

The variance in estimates of soil moisture as determined by the neutron-scattering method is examined and related to field data from two research areas. Instrument and timing errors are shown to contribute insignificantly to the standard error of estimate. Furthermore, their contribution to estimates of moisture change with time is negligible as long as the timing interval used at each observation exceeds 30 seconds.

266. **Hewlett, J. D.; Fortson, J. C.; Cunningham, G. B. 1977.** The effect of rainfall intensity on storm flow and peak discharge from forest land. Water Resources Research. 13: 259-265.

Analysis of a 30-year record of rainfall and stormflow (545 events) from a forested watershed in the Southern Appalachians was made to determine whether rainfall intensity influences stormflow volume or peak discharge. For all practical purposes, rainfall intensities during storms had no effect on stormflow volumes. Storm rainfall, antecedent flow, season, and duration of the rainstorm accounted for 86.4 percent of total variation in the log of stormflow. Addition of maximum 60-, 30-, 15-, and 5-minute intensities raised this to 86.7 percent. Only 4.7 percent of the total variation in the log of peakflow was attributable to intensity.

267. **Hewlett, J. D.; Fortson, J. C.; Cunningham, G. B. 1984.** Additional tests on the effect of rainfall intensity on storm flow and peak flow from wild-land basins. Water Resources Research. 20: 985-989.

Further evidence that hourly rainfall intensity has no appreciable effect on stormflows, and only a small effect on peakflows, was adduced from statistical analysis of 4094 storm events on 15 drainage basins ranging from 13 to 760 ha. The basins range from humid to semiarid climates and from flat to steep topography and contain various covers (forest, brush, grass, and swamp). The marginal coefficient of determination accounted for by maximum hourly rain intensity averaged about 1 percent for stormflows and about 10 percent for peakflows. The dependence of stormflows on rain intensity did not increase in larger storms or on more responsive basins, but rather the opposite.

268. **Hewlett, John D.; Helvey, J. D. 1970.** Effects of forest clear-felling on the storm hydrograph. Water Resoures Research. 6: 768-782.

A statistical analysis of all major storm hydrographs before and after clear-felling a mature hardwood forest on a 108-acre calibrated catchment revealed that, after felling,

stormflow volume was significantly (0.001 level) increased 11 percent overall, or 0.23 inch at the mean stormflow volume of 2.1 inches. Peak discharge increased slightly after felling (about 6 c.f.s.m. or 7 percent at the mean peakflow of 92 c.f.s.m.). Time to peak, recession time, and duration of stormflow were tested to an accuracy within 10 percent of their respective mean values (0.05 level), but no treatment effect was detected. Increases in stormflow as a result of felling ranged from 0 in small floods to 1.9 inches during a record 7-day flood sequence.

269. **Hewlett, John D.; Hibbert, A. R. 1961.** Increases in water yield after several types of forest cutting. International Association Scientific Hydrology Bulletin. 6(3): 5-17.

Effects of timber and brush removal on water yields from small watersheds are examined in the light of 25 years of hydrologic research at Coweeta.

270. **Hewlett, John D.; Hibbert, Alden R. 1963.** Moisture and energy conditions within a sloping soil mass during drainage. Journal of Geophysical Research. 68: 1081-1087.

A model of a sloping soil profile is used to show that slow, unsaturated flow of soil moisture above the water table furnishes much of the sustained streamflow between storms in mountain land.

271. **Hewlett, John D.; Hibbert, Alden R. 1966.** Factors affecting the response of small watersheds to precipitation in humid areas. In: Proceedings of a National Science Foundation advanced science seminar, international symposium of forest hydrology; 1965 August 29 - September 10; University Park, PA. Oxford; New York: Pergamon Press: 275-290.

A numerical rating system, the response factor, was developed from precipitation and streamflow records for use in classifying the hydrologic response of small watersheds in humid areas. Long-term hydrograph records from 15 forested watersheds in the Eastern United States were separated into quick and delayed flow by computer and ranked according to mean precipitation, quick flow, and the response factors quick flow/precipitation and quick flow/total water yield.

272. **Hewlett, John D.; Kramer, P. J. 1963.** The measurement of water deficits in broadleaf plants. Protoplasma. 57: 381-391.

A comparison of the disk technique with Stocker's whole leaf method for determining water deficit of some hardwood trees reveals confusion in existing terms and methods. The water relations of leaf disks cut from broadleaf trees cannot be assumed to be the same as whole leaves, because more water per unit weight is usually required to saturate excised disks. Stocker's term "wasser defizit" and the whole leaf method, when modified to allow shorter equilibration schedules, remain the best way to express and measure water deficits in forest trees.

273. **Hewlett, John D.; Metz, L. J. 1960.** Watershed management research in the Southeast. Journal of Forestry. 58: 269-271.

This article is a review of research on watershed management at the Coweeta Hydrologic Laboratory and Union Research Center.

274. **Hewlett, John D.; Nutter, Wade L. 1970.** The varying source area of streamflow from upland basins. In: Interdisciplinary aspects of watershed management: Proceedings of the symposium; 1970 August 3-6; Bozeman, MT. New York: American Society of Agricultural Engineers: 65-83.

The variable source area concept of upland streamflow may soon become a working model to account for the various sources, pathways, and timing delays which underlie the dynamics of discharge from headwater areas. The variable source area concept is substantially different from the traditional view of storm or flood flow as a hydrograph of surface runoff. By ignoring infiltration, which has not been connected quantitatively to the hydrograph, the model has the freedom to accommodate the more important dynamic aspects of the streamflow production process.

275. **Hewlett, John D.; Patric, J. H. 1963.** An example of multiple use on a small mountain watershed. In: Proceedings, 7th annual meeting, Soil Conservation Society of America, Georgia Chapter; Vol. 3. 1963 May 24-25; Eatonton, GA. Eatonton, GA: Soil Conservation Society of America, Georgia Chapter: 12-26.

An example of multiple use on a 356-acre watershed at Coweeta Hydrologic Laboratory is presented. This report discusses the concept of forest access as being the key to management. Plans for management of the area for water, timber, wildlife, and recreational values are presented.

276. **Hewlett, John D.; Patric, James H. 1963.** A pilot test of multiple use on a small mountain watershed. In: Proceedings, 42d annual meeting, Society of American Foresters, Appalachian section; 1963 February 8-9; Greenville, SC. Charlottesville, VA: Society of American Foresters: 11-18.

A pilot test of the multiple-use concept on a 356-acre watershed at Coweeta Hydrologic Laboratory is presented. This report discusses that concept in terms of management of the area for water, timber, wildlife, and recreational values. A proper access system is cited as the key to effective resource management.

277. **Hibbert, A. R. 1969.** Water yield changes after converting a forested catchment to grass. Water Resources Research. 5: 634-640.

After a forested catchment was converted to grass, the amount of evapotranspiration was closely related to the amount of grass produced. During years when grass production was high, water yield from the catchment was about the same as or less than the expected yield from the original forest. As grass productivity declined, water yield gradually increased until it exceeded the predicted

yield from the forest by over 5 inches annually. The grass appeared to evaporate more water early in the spring and less water late in the summer than the original forest cover.

278. **Hibbert, A. R.; Troendle, C. A. 1988.** Streamflow generation by variable source area. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 111-127.

For many years, hydrologists and engineers alike have attempted to describe and model the processes that generate streamflow from rainfall. The Hortonian concept of stormflow generation prevailed for many years, and is still valid when applied to land surfaces that do not accept water readily. But the concept of a subsurface source for stormflows requires a dynamic process. Channel precipitation is the first contributor to stormflow and for short, intense storms it may be the only contributor. Second to contribute are areas of shallow-water table close to the stream (springheads, seepages, and swamps that are quickly saturated by rainfall). Where such conditions occur, there will be an increase in effective width of channel and, thus, increase in the channel area available for precipitation interception. For extended storms, water moving down slope through layers of porous soil could reach the stream in time to contribute to the storm hydrograph.

279. **Hibbert, Alden R. 1966.** Forest treatment effects on water yield. In: Proceedings of a National Science Foundation advanced science seminar: International symposium on forest hydrology; 1965 August 29 - September 10, University Park, PA. New York: Pergamon Press: 527-543.

Results are reported for 39 studies of the effect of altering forest cover on water yield. Taken collectively, these studies reveal that forest reduction increases water yield and that reforestation decreases water yield.

280. **Hibbert, Alden R.; Cunningham, G. B. 1966.** Streamflow data processing opportunities and application. In: Proceedings of a National Science Foundation advanced science seminar: International symposium of forest hydrology; 1965 August 29 - September 10; University Park, PA. New York: Pergamon Press: 725-736.

The techniques used at the Coweeta Hydrologic Laboratory for processing streamflow records from recorder charts and analog-to-digital recorder tape to final integration of discharge are discussed in detail.

281. **Hill, Jennifer; Grossman, Gary D. 1987.** Effects of subcutaneous marking on stream fishes. Copeia. (2): 492-495.

A long-term marking technique for fishes must permit a large number of unique marks, be long lasting, not increase mortality, diminish growth, or alter behavior, and be inexpensive and usable in the field. Subcutaneous injections with acrylic paints generally satisfy these criteria. In previous studies, fish were marked in one position or with a single color; hence, the effects of mark position or color on recapture frequency are unknown. Herein, we evaluate the effects of mark position and color on growth, survivorship, longevity, and recapture success for several southeastern stream fishes.

282. **Hill, Jennifer; Grossman, Gary D. 1987.** Home range estimates for three North American stream fishes. Copeia. (2): 376-380.

Home ranges of three fish species inhabiting a fourth order stream in the Blue Ridge Mountains of North Carolina were estimated. *Cottus bairdi*, *Rhinichthys cataractae* and *Clinostomus funduloides* moved an average of 12.9, 13.4, and 19.3 m, respectively, between captures. Mean time interval between captures was 128 days; 86 percent of recaptures were in the stream section of previous capture. Individuals may not have moved throughout the entire section length (mean length = 10.4 m); thus, these values likely overestimate actual movements.

283. **Hilmon, Junior B.; Douglass, James E. 1968.** Potential impact of forest fertilization on range, wildlife, and watershed management. In: Forest fertilization theory and practice symposium; 1967 April 18-27; Gainesville, FL. Muscle Shoals, AL: Tennessee Valley Authority: 197-202.

This paper reviews the impacts of forest fertilization on forage, wildlife, and water resources.

284. **Hogg, D. C. 1968.** Millimeter-wave communication through the atmosphere. Science. 159(3810): 39-46.

Millimeter-length radio wave bands are not utilized for communication because water vapor in the atmosphere absorbs energy at these frequencies and limits distance of transmission. Rain is one of several causes of radio-wave attenuation discussed in this review. Data collected for the Illinois State water survey by a raindrop camera at Coweeta Hydrologic Laboratory are used with data from other sites to estimate the degree of radio interference and develop design guidelines for communications systems.

285. **Hogue, Charles L.; Georgian, Ted. 1986.** Recent discoveries in the *Blepharicera tenuipes* group, including descriptions of two new species from Appalachia (Diptera: Blephariceridae). Contributions in Science. 377: 1- 20.

Two new species of *Blepharicera (B. appalachiae* and *coweetae*) are described in the *Blepharicera tenuipes* group. Both occur in the southern half of the Appalachian Mountains in eastern North America, the former of wide distribution, the latter restricted to a small portion of the upper Little Tennessee drainage. A key to all the known stages in the *B. tenuipes* group is provided along with new information on ecology, distribution, and phylogeny (for which the sister *Blepharicera micheneri* group is newly recognized).

286. **Hoover, M. D. 1944.** Effect of removal of forest vegetation upon water yields. Transactions, American Geophysical Union. Part 6: 969-977.

A clearcutting experiment on Coweeta Watershed 17 is described, and effects of the cutting and subsequent treatment on increasing water yield are presented. Peak discharges were not significantly increased by the cutting, and surface runoff did not occur after treatment. Data indicate that a forest stand annually transpires 17 to 22 inches of water.

287. **Hoover, M. D. 1945.** Careless skidding reduces benefits of forest cover for watershed protection. Journal of Forestry. 43: 765-766.

Careless skidding creates channels which concentrate runoff from road surfaces and cause erosion, which is unnecessary if roads are carefully located and constructed. Techniques which minimize erosion from skid roads are presented.

288. **Hoover, M. D. 1952.** Water and timber management. Journal of Soil and Water Conservation. 7: 75-78.

As demand for water increases, management of forested headwaters assumes greater importance. Compatibility of objectives in the management of timber and water is demonstrated, and management practices which protect the values of each resource are stressed.

289. **Hoover, M. D.; Hursh, C. R. 1943.** Influence of topography and soil depth on runoff from forest land. Transactions, American Geophysical Union. Part 2: 693-698.

Data are presented on rainfall and discharge for seven watersheds at Coweeta during a storm on December 27-29, 1942. The difference in peak discharges is assigned in part to higher rainfall at higher elevations, but peaks were also related to soil depth, topography, and hydrologic characteristics associated with different elevations.

290. **Hoover, M. D.; Hursh, C. R. 1943.** Installation of shallow observation wells. Tech. Note 56. Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 5 p.

The location, installation, and operation of shallow groundwater observation wells are described. This Note is of value to field personnel involved in well installation and in the analysis of observations taken from wells constructed by the methods described.

291. **Hoover, M. D.; Lunt, H. A. 1952.** A key for the classification of forest humus types. Proceedings, Soil Science Society of America. 16(4): 368-370.

A key is presented for classifying major organic layers into Mull, Duff Mull, and Mor. It is applicable for well- and moderately well-drained soils. Basic criteria in the classification are (1) presence or absence of an H layer; (2) the degree of incorporation of organic matter into the upper mineral soil; and (3) the structure, thickness, and organic content of the H layer and the A horizon.

292. **Hornbeck, James W.; Swank, Wayne T. 1992.** Watershed ecosystem analysis as a basis for multiple-use management of eastern forests. Ecological Applications. 2(3): 238-247.

There is ever-increasing competition for the many uses and natural resources of forests in the Eastern United States. Multiple-use management has long been a stated goal for the forests, but application has been problematic and seldom satisfactory to all users. There is a need to incorporate more science into management decisions for eastern forests, and thereby convincingly demonstrate to forest managers and the public why certain combinations of uses may or may not be compatible. One proven approach for doing this is to use watershed ecosystem analysis. Small watersheds, usually <100 ha, serve as convenient ecosystems for studying how forests function in terms of cycling energy, nutrients, and water. Results of these studies allow assessments of forest health and productivity, and evaluations of impacts of both natural and human-related disturbances. This paper provides illustrations of how watershed ecosystem analysis can be used to study the effects of current harvesting practices, acidic deposition, and past land use. The paper also shows how recommendations for land use are derived from watershed ecosystem analysis, and how they are put into practice.

293. **Hornick, L. E.; Webster, J. R.; Benfield, E. F. 1981.** Periphyton production in an Appalachian Mountain trout stream. American Midland Naturalist. 106: 22-36.

Periphyton primary production was investigated in one second-order Appalachian Mountain stream and two of its tributaries. Using ^{14}C fixation in recirculating chambers, estimates averaged 2.27 mg C m/h in the mainstream and 1.65 and 1.37 mg C m/h in the two tributaries. Abiotic factors most influential on primary production rates were light, streamflow, and inorganic carbon. Based on annual budgets, the estimated stream energy input attributable to autochthonous primary production was about 3 percent of allochthonous inputs. However, because of high nutritive value and timing, autochthony may be more important than indicated by annual budgets.

294. **Huff, D. D.; Begovich, C. L. 1976.** An evaluation of two hydrograph separation methods of potential use in regional water quality assessment. ORNL/TM-5258. Oak Ridge, TN: Oak Ridge National Laboratory, Environmental Sciences Division. 112 p. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Streamflow data are more useful for evaluating hydrologic model results and studying water quality once baseflow and storm runoff have been separated by an appropriate technique. The Snyder and Curlin and the Coweeta methods were evaluated as to conceptual basis, ease of application, cost of data processing, and acceptability of results. The quick flow hydrograph separation method, in use at the Coweeta Hydrologic Laboratory, was selected for use because it gives acceptable results and is easy and

inexpensive to use. The Coweeta program should be useful in developing regional quantitative relationships between changes in land use and changes in runoff and water quality.

295. **Huff, D. D.; Swank, W. T. 1985.** Modeling changes in forest evapotranspiration. In: Anderson, M. G.; Burt, T. P., eds. Hydrological forecasting. Chichester, UK: John Wiley and Sons: 125-151.

This paper discusses PROSPER, a one-dimensional evapotranspiration model that links atmosphere, vegetation, and underlying soils through use of simultaneous equations that combine energy balance, mass transport, and soil moisture dynamics. Topics discussed include the model structure and individual components, previous applications of PROSPER, and application of the model to WS 13 at Coweeta for a 15-year coppice regrowth period following clearcutting. The long-term simulations indicate that PROSPER, when used with published parameter values, tends to underestimate actual evapotranspiration and the effects of leaf area index reductions, although simulated responses are within about 10 percent of long-term experimental values.

296. **Huff, D. D.; Swank, W. T.; Troendle, C. A.; Henderson, G. S.; Waide, J. B.; Haynes, T. 1978.** Element cycles and water budget analysis applied to forest management in the Eastern United States. In: Proceedings, Society of American Foresters; 1978 October 23; St. Louis, MO. Washington, DC: Society of American Foresters: 77-89.

Ecosystem science has made significant advances in the past several years that can provide information useful in the evaluation of environmental and resource management issues. Examination of nutrient budgets has shown that concentrations of all dissolved nutrients in stream discharge from watersheds altered by cutting, species conversions, and changes in land use remained low after manipulations. None of the treatments produced long-term elevated nutrient levels that would adversely affect water use. However, simulations suggest that elevated losses of NO_3-N associated with harvesting may cause a significant decline in the nitrogen pool of the forest ecosystem. Furthermore, nitrogen depletion may increase with increasing time of management, and complete-tree harvest probably results in the greatest nitrogen depletions of any cutting alternative.

297. **Hursh, C. R. 1928.** Litter keeps forest soil productive. Southern Lumberman. 133(1734): 219-221.

Forest soils are, for the most part, self-fertilized by organic material derived from litter. Litter has a beneficial effect on the ability of soil to absorb and retain moisture, on chemical characteristics, and on biological activity. The effects of fire and aspect on litter production are discussed.

298. **Hursh, C. R. 1931.** Abandoned mountain farms an erosion menace but a forestry opportunity. Farmers Federation News. 11(12): 3, 5.

The author describes agricultural practices which leave mountain soils exposed to erosion and recommends that slopes unsuitable for agriculture not be cleared and that abandoned land be converted to pasture or forest cover to prevent erosion.

299. **Hursh, C. R. 1935.** Control of exposed soil on road banks. Tech. Note 12. Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 4 p.

Increased erosion, siltation, and road maintenance can be largely eliminated by covering road banks with litter or revegetating banks at the time of road construction. The simplest and most practical measures include planting, seeding, and use of stake and brush wattles. Selection of suitable plant species is discussed.

300. **Hursh, C. R. 1937.** Frog makes record. Bull. 21(16). Washington, DC: U.S. Department of Agriculture, Forest Service. 6 p.

The recording of the journeys of a small frog on the float of a water-level recording instrument in a ground-water observation well is described.

301. **Hursh, C. R. 1938.** Mulching for road bank fixation. Tech. Note 31. Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 4 p.

Road bank fixation on dry, infertile sites is particularly troublesome, and the use of mulches on dry and infertile banks at the time banks are planted is the most successful and inexpensive method of stabilization. Transplanting of woody shrubs offers no particular problem. Two general methods of mulch application are (1) staked weed mulches and (2) staked brush and litter mulches. The author lists materials, equipment, labor requirements, and procedures for mulch application.

302. **Hursh, C. R. 1939.** Roadbank stabilization at low cost. Tech. Note 38. Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 20 p.

Low-cost methods of establishing vegetation on cut-and-fill slopes of roadbanks are described. Planting and seeding without preliminary stabilization are too expensive for extensive use. Two types of mulch application–staked weed mulches and staked brush and litter mulches–are outlined. Requirements for labor and equipment are listed, and procedures for mulch application are discussed.

303. **Hursh, C. R. 1940.** Outline for compiling precipitation and runoff data from small drainage areas. Tech. Note 34. Asheville, NC: U. S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 59 p.

This is the original description of procedures used by the Station for the systematic compilation of continuous records of precipitation and stream discharges.

304. **Hursh, C. R. 1941.** The geomorphic aspects of mudflows as a type of accelerated erosion in the Southern Appalachians. Transactions, American Geophysical Union. Part 2: 253-254.

Under certain conditions, high infiltration rates and deep soils give rise to conditions which cause mudflows. After prolonged rainfall, the soil mass is surcharged with water; a major surface break, such as uprooting of large trees, may start mass movement. The nature of movement of the soil mass depends on the slope of the contact zone with stable material.

305. **Hursh, C. R. 1942.** The naturalization of roadbanks. Roads and Bridges (Can.). 80(7): 22-26, 131-134.

Naturalization and stabilization of roadbanks by vegetation are discussed as part of road construction. Experiments begun in 1934 at the Appalachian Forest Experiment Station indicate that seeding, planting, fertilizing, and mulching are methods of stabilizing banks.

306. **Hursh, C. R. 1942.** The naturalization of roadbanks. Tech. Note 51. Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 36 p.

The problems involved in natural stabilization of roadbanks, including the factors limiting plant growth and the origin and causes of soil stability, are discussed. Suggestions are given for stabilization of banks with different slopes and with moist, fertile soil and dry, infertile soil. Establishment of vegetation with commercial fertilizers, seeding, planting, and mulches is discussed.

307. **Hursh, C. R. 1942.** Naturalized roadbanks. Better Roads. 12(6): 13-15, 24-25; 12(7): 17-20.

Naturalization and stabilization of roadbanks by vegetation are discussed as part of road construction. Experiments begun in 1934 at the Appalachian Forest Experiment Station indicate that seeding, planting, fertilizing, and mulching are practical methods of stabilizing banks.

308. **Hursh, C. R. 1943.** Discussion of paper entitled "Determination of the Effects of Watershed-Management on Mountain Streams" by C. L. Wicht. Transactions, American Geophysical Union. 24(II): 606-608.

Elimination of the effects of climatic variability and factors such as size, shape, and soil-depth of watersheds through various statistical methods is questioned. Statistical methods are recognized as valuable research tools, but in order to develop practical watershed management techniques, the very factors to be eliminated in the experimental design must be evaluated. The concept of watershed standardization over a period of years is discussed as a procedure which eliminates comparison of the physical characteristics of one watershed with those of another.

309. **Hursh, C. R. 1944.** Water storage limitations in forest soil profiles. Proceedings, Soil Science Society of America. 8: 412-414.

At Coweeta, measurements of macropore space were used to estimate differences in water storage between natural forest soil and soil from pine stands on eroded old-field land.

310. **Hursh, C. R. 1944.** Appendix B–report of sub-committee on subsurface-flow. Transactions, American Geophysical Union. Part 5: 743-746.

Literature on subsurface flow is reviewed, and the lack of records from suitable experimental watersheds is cited as a handicap in interpreting the nature of subsurface stormflow.

311. **Hursh, C. R. 1945.** Plants, shrubs, trees in slope stabilization. Contractors and Engineers Monthly. 42(6): 26-27.

Natural vegetation is the most efficient and esthetically pleasing means of roadbank stabilization. Deep-rooted legumes such as perennial lespedeza and Scotch broom together with native woody shrubs are advised. In the Eastern States, rainfall and site conditions favor a plant succession toward a forest cover, but the possibility of trees being uprooted or interfering with viewing distance shoud be taken into account.

312. **Hursh, C. R. 1946.** The eastern forester and his watersheds. Journal of Forestry. 44: 1037-1040.

Author pointedly questions whether the average forester is trained to manage water resources of the forest. Basic concepts of geophysical science (soils, climatology, and the origin and distribution of water on the earth's surface) are discussed in relation to the water resource and its management.

313. **Hursh, C. R. 1946.** Watershed management, 1931-1946. Annual Report of the Appalachian Forest Experiment Station. Asheville, NC: U.S. Department of Agriculture, Forest Service, [Southeastern Forest Experiment Station]. 43-50.

This is a progress report of the activities at Coweeta Hydrologic Laboratory and Copper Basin from 1931 to 1946.

314. **Hursh, C. R. 1946.** Where little waters write big stories. American Forests. 52: 574-577, 603.

The author describes watershed experiments underway at the Coweeta Hydrologic Laboratory and discusses what has been learned about water yield and erosion from studies of complete removal of forests, of clearing and cultivating steep forest lands, and of woodland grazing.

315. **Hursh, C. R. 1947.** Water resource management. North Carolina Engineer. 3(2): 9-12, 40.

This article is a general summary on the research facilities, program, and findings at the Coweeta Hydrologic Laboratory.

316. **Hursh, C. R. 1947.** Watershed experiments conducted in giant outdoor laboratory. Timber Topics. 10(4): 2-4, 9.

The author reviews the objective of watershed research at the Coweeta Hydrologic Laboratory and discusses the effects on water yield of clearing and cultivating steep forest lands, of complete removal of forest trees, of woodland grazing, and of logging and burning watersheds.

317. **Hursh, C. R. 1948.** Local climate in the Copper Basin of Tennessee as modified by the removal of vegetation. Circ. 774. Washington, DC: U.S. Department of Agriculture. 38 p.

Meteorological records were collected from three contiguous land areas that once supported a uniform hardwood forest but are now characterized by three distinct vegetative conditions: forest, grass, and bare soil. Differences in air and soil temperatures, wind, evaporation, moisture saturation deficit of the air, and rainfall indicate that each vegetative zone possesses a distinctive local climate.

318. **Hursh, C. R. 1949.** Climatic factors controlling roadside design and development. Proceedings, National Highway Research Board. Washington, DC: National Research Council: 9-19.

Factors which influence the revegetation of roadbanks–drying by wind, soil temperatures, frost action, mulching, and road design–are discussed.

319. **Hursh, C. R. 1951.** Research in forest-streamflow relations. UNASYLVA. 5: 2-9.

The objectives of the research program at the Coweeta Hydrologic Laboratory are defined, and current watershed studies are described. The practical significance of research findings in the management of watershed resources is discussed.

320. **Hursh, C. R. 1951.** Watershed aspects of the New York water supply problems. Journal of Forestry. 49: 442-444.

Watershed aspects of New York's problems with water supply from the Croton and Catskill systems are discussed. Past practices in forest conservation have contributed to the development and protection of these systems. However, complete closure is not synonymous with watershed management; vegetative management is often a direct means of improving soil and increasing water resource values. Watershed problems which merit further consideration are listed by priority.

321. **Hursh, C. R. 1952.** Forest management in East Africa in relation to local climate, water and soil resources. Annual report of E.A.A.F.R.O. Nairobi, Kenya: East African Agriculture and Forestry Research Organization: 26-35.

As a Fulbright Research Scholar, the author presents his views on east Africa's need for expansion of farm forestry, improvement of damaged local climate, management of grazed areas, and catchment management and research.

322. **Hursh, C. R. 1952.** Now is the time. Farmers Federation News. 32(7): 12

Owners of idle land are urged to initiate conservation measures. The value of trees for protection against erosion, stream sedimentation, and local floods is emphasized.

323. **Hursh, C. R. 1952.** Water from the family spring. Living Wilderness. 16(39): 11-12.

The part a spring plays in rural family life is described.

324. **Hursh, C. R.; Brater, E. F. 1941.** Separating storm-hydrographs from small drainage-areas into surface- and subsurface-flow. Transactions, American Geophysical Union. Part 3: 863-871.

This classic study of hydrographs from streams and ground-water wells demonstrates that hydrographs from forested catchments at Coweeta are comprised of channel precipitation and various subsurface flow components rather than overland flow. In accounting for the stormflow volume, the authors describe five sources of stormwater. They also describe the process which became known 20 years later as the concept of variable source area.

325. **Hursh, C. R.; Connaughton, C. A. 1938.** Effects of forests upon local climate. Journal of Forestry. 36: 864-866.

Early studies of the effects of forests on climate as authorized in the United States under the McSweeney-McNary Forest Research Act of 1928 are described. Indications are that forests exert little influence on climate of large areas but have a marked effect on local or environmental climate. Observations were made at Copper Basin, a 7000-acre area completely denuded by smelter fumes, and in the adjacent hardwood forest. The information obtained on microclimate has application in studies of fire, shelter-belts, forest management, and watershed management.

326. **Hursh, C. R.; Craddock, G. W. 1949.** Review on book "Hydrology" by C. O. Wisler and E. F. Brater. Journal of Forestry. 47: 844-845.

Review of the new standard text on wild land hydrology.

327. **Hursh, C. R.; Crafton, W. M. 1935.** Plant indicators of soil conditions on recently abandoned fields. Tech. Note 17. Asheville, NC: U.S. Department of Agriculture, Forest Service, Appalachian Forest Experiment Station. 3 p.

Growing conditions on abandoned farm fields to be reforested are indicated by the species of plants present. Plant indicators which serve as guides in the selection of tree species and planting methods are given for four grades of sites, as determined by the amounts of soil moisture and

nutrients present. Plant succession on each of these sites is discussed.

328. **Hursh, C. R.; Fletcher, P. W. 1942.** The soil profile as a natural reservoir. Proceedings, Soil Science Society of America. 7: 480-486.

A 7-acre watershed was intensively instrumented with groundwater wells to test the concept that the soil profile has a measurable storage capacity and a regulating effect on ground-water discharge. Well elevations were correlated with measured discharge so that aquifer dimensions and porosity required for detention storage could be estimated. Three types of reservoir functions of the soil profile were recognized.

329. **Hursh, C. R.; Haasis, F. W. 1931.** Effects of 1925 summer drought on Southern Appalachian hardwoods. Ecology. 12: 380-386.

Total rainfall recorded at Asheville, NC, from May to August 1925 was 5.11 inches, whereas the normal is 15.97 inches. Trees on ridges and upper slopes between 2100 and 2600 feet elevation became wholly or partially brown during August and September, and some species (chiefly oaks and shortleaf and pitch pines) experienced premature leaf fall. Leaf browning and early fall were more pronounced on younger trees and were particularly severe on dogwood, sourwood, and chestnut. Chestnut oaks and pine survived on areas where black oaks were completely killed.

330. **Hursh, C. R.; Hoover, M. D. 1941.** Soil profile characteristics pertinent to hydrologic studies in the Southern Appalachians. Proceedings, Soil Science Society of America. 6: 414-422.

The two most essential profile characteristics in hydrologic studies–retention and detention storage–are functions of soil porosity, water-storage opportunity, and transmission rate of water. Detention storage is measured as noncapillary porosity. Retention storage is measured in terms of additional water of specific retention needed to satisfy capillary requirements. The characteristics of pore space in the soil mass can be easily determined by utilizing the principle of water displacement of air from undisturbed volume samples.

331. **Hursh, C. R.; Hoover, M. D.; Fletcher, P. W. 1942.** Studies in the balanced water-economy of experimental drainage-areas. Transactions, American Geophysical Union. Part 2: 509-517.

In this intensive study of the water balance, estimates of precipitation, ground-water and surface-water flow, and evapotranspiration are the factors used to account for water circulating through a watershed system.

332. **Hursh, C. R.; Lieberman, J. A. 1946.** Watershed management in the Southeastern States. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Knowledge gained at Coweeta from cutting forest stands, unrestricted logging, mountain farming, and woodland grazing is related to good watershed management in the Southeast.

333. **Hursh, C. R.; Pereira, H. C. 1953.** Field moisture balance in the Shimba Hills, Kenya. East Africa Agricultural Journal 18(4): 1-7.

This article draws on limited observations and field measurements to reconstruct and compare the moisture balance of the grass-covered and depleted Shimba Hills of Kenya with that under a natural forest. The natural forest, which once occupied the Shimba Hills, is a more desirable cover than grass for maximum-sustained water yield because water additions from mist and dew are greater from the forest.

334. **Hursh, Charles R.; Barrett, Leonard I. 1931.** Forests of Georgia highlands; their importance for watershed protection, recreation and wood production. Bull. 15. Macon, GA: Georgia Forest Service. 32 p. In cooperation with: U.S. Forest Service, Appalachian Forest Experiment Station; Georgia Agricultural Experiment Station.

The results of an early investigation of the value of Georgia's mountain forests with respect to timber production, watershed protection, and recreation use are presented.

335. **Huryn, A. D. 1985.** A new species of *Hydroptila* (Trichoptera: Hydroptilidae) from North Carolina. Proceedings of the Entomology Society of Washington. 87: 444-447.

Adult specimens of a previously unknown member of the *tineodes* species group of *Hydroptila*, were reared from pupae collected from a high elevation catchment. The male, female and terminal instar larva of *Hydroptila coweetensis* n. sp. are described and available biological information is given.

336. **Huryn, Alexander D. 1990.** Growth and voltinism of lotic midge larvae: patterns across an Appalachian Mountain basin. Limnology and Oceanography. 35(2): 339-351.

The influence of thermal regime upon community-level growth rates and voltinism was estimated for larval Chironomidae inhabiting litter accumulations in four streams. Groups of larvae were confined in growth chambers and incubated in situ at time intervals representing the observed range of annual thermal variation. Estimates of daily growth rates (g) were derived from change in average length over the incubation period. Temperature and larval size had significant positive and negative effects on g, respectively. Equations derived for each stream described a substantial proportion of the variance but did not differ significantly. Therefore, the data from all streams were combined to derive a single general equation which, along with larval size distribution, biomass, and temperature data, was used to model the

variation in annual biomass turnover (G) and hypothetical size-dependent voltinism among the study streams. The model provides evidence that spatial variation of G on the order of 31 percent can be expected for midge communities within a <30 km^2 area of this Appalachian Mountain basin.

337. **Huryn, Alexander D.; Wallace J. Bruce. 1985.** Life history and production of *Goerita semata* Ross (Trichoptera: Limnephilidae) in the southern Appalachian Mountains. Canadian Journal of Zoology. 63: 2604-2611.

Populations of *Goerita semata* are restricted to moss- or liverwort-covered rock faces located in small, heavily shaded high-elevation streams. The larval developmental period was completed in about 655 days with two distinct cohorts being present at any time. Growth was slow, averaging only 0.71 percent ash-free dry mass per day. In spite of low growth rates, relatively high production was maintained by high larval densities. Production in the rock-face habitat was 237.66 mg ash-free dry mass/m^2/yr. Most growth occurred during the spring and was correlated with increases in water temperature and in diatom consumption by the larvae. During the spring, diatoms composed about 64 percent of the foregut contents. In contrast, amorphous detritus constituted about 91, 65, and 86 percent of the gut contents during the fall, winter, and summer, respectively. Diatom consumption was estimated to be responsible for 58 percent of the annual production.

338. **Huryn, Alexander D.; Wallace, J. Bruce. 1986.** A method for obtaining in situ growth rates of larval Chironomidae (Diptera) and its application to studies of secondary production. Limnology Oceanography. 31(1): 216-222.

Methods and growth chambers are described which permit in situ estimates of the growth rates of chironomid larvae inhabiting litter accumulations in lotic habitats. Instantaneous growth rates (IGRs) for larvae of different sizes ranged from 0.01 to 0.24 mg/mg ash-free dry mass (AFDM) per day at stream temperatures of 2.9 - 15.1° C. IGRs were significantly and linearly related to temperature. Regression equations relating IGRs and temperature, combined with field-derived data for chironomid standing stock and stream temperature, enabled calculation of the production of chironomids inhabiting litter accumulations in a temperate mountain stream. The annual production per litter bag was about 224 mg AFDM per year and the annual P:B was 42, indicating rapid turnover of chironomid biomass. The annual production of chironomids exceeded the mean standing crop biomass of all macroinvertebrates by 4.6 x.

339. **Huryn, Alexander D.; Wallace, J. Bruce. 1987.** The Exopterygote insect community of a mountain stream in North Carolina, USA: life histories, production, and functional structure. Aquatic Insects. 9(4): 229-251.

Life histories and production of the Exopterygota inhabiting a first- to second-order mountain stream were studied by replicated monthly sampling of three different habitats. Production was distributed evenly among four functional groups with collector-gatherers, shredders, scrapers, and engulfing-predators contributing 21, 33, 23, and 23 percent, respectively. Annual production by the Exopterygota was greatest in the boulder-outcrop habitat. Sixty-five percent of production was based on a collector-gatherer, but this group constituted only 2 and 8 percent of pool and riffle production. Comparison of the functional structure of the exopterygote communities of headwaters with higher order streams indicated a shift from a dominance of detritivory to predation.

340. **Huryn, Alexander D.; Wallace, J. Bruce. 1987.** Local geomorphology as a determinant of macrofaunal production in a mountain stream. Ecology. 68(6): 1932-1942.

Local geomorphology determined the diversity and spatial distribution of bedrock-outcrops, riffles, and pools in an Appalachian mountain stream. In turn, the functional structure of the macrofauna was the result of the relative contributions of each habitat type. By replicated monthly sampling, substrate particle-size distributions, current velocity, standing crops of benthic organic matter, and production of macrofauna were measured in each of three principal habitats. The bedrock-outcrop habitat was characterized by high material entrainment and export as indicated by significantly higher current velocities and lower standing crops of detritus compared to the riffle and pool habitats. Pools were sites of low entrainment and high retention of organic matter as demonstrated by significantly lower current velocities and higher accumulations of detritus than other habitats. The riffle habitat was intermediate to the bedrock-outcrop and pool habitats in all parameters measured.

341. **Huryn, Alexander D.; Wallace, J. Bruce. 1987.** Production and litter processing by crayfish in an Appalachian Mountain stream. Freshwater Biology. 18: 277-286.

Mean annual density and biomass of *Cambarus bartonii* in a mountain stream was 12 individuals/m^2 and 1669 mg/m^2. While *C. bartonii* constituted 61 percent of the total macroinvertebrate biomass, it contributed only 13 percent of annual community secondary production. Litter processing was positively related to temperature and crayfish size. We speculate that during summer, crayfish play an important role in temperate woodland streams by converting slowly processed leaf litter species (e.g., *Rhododendron*) to fine particles which are then available to collector-gatherers.

342. **Huryn, Alexander D.; Wallace, J. Bruce. 1988.** Community structure of Trichoptera in a mountain stream: spatial patterns of production and functional organization. Freshwater Biology. 20: 141-155.

Annual production was estimated for Trichoptera occurring in three stream habitats of WS 27. Production was greatest on bedrock-outcrops, followed by riffles and pools. Annual production in bedrock-outcrops and pools was dominated by single functional groups, collector-filterers

and shredders, respectively. Production in riffles was due to a combination of shredders and collector-filterers. Habitat-weighted production was distributed among functional groups: collector-filterers (41 percent), shredders (29 percent), engulfing-predators (15 percent), scrapers (13 percent), and collector-gatherers (2 percent). The distinct taxonomic and functional structures of trichopteran subcommunities were shaped by the physical characteristics of their principal habitats.

343. **Johnson, D. W.; Kelly, J. M.; Swank, W. T.; Cole, D. W.; Van Miegroet, H.; Hornbeck, J. W.; Pierce, R. S.; Van Lear, D. 1988.** The effects of leaching and whole-tree harvesting on cation budgets of several forests. Journal of Environmental Quality. 17(3): 418-424.

Coordinated studies of the effects of acid deposition, natural leaching, and whole-tree harvesting (WTH) on base cation export from forests in Maine, Tennessee, South Carolina, North Carolina, and Washington showed that base cation export via WTH would be nearly independent of soil exchangeable base cation supplies while base cation export via leaching would be strongly dependent on the exchangeable cation supplies as well as the input, production, and mobility of anions. Mixed deciduous sites in Tennessee had among the highest base cation (principally Ca) exports via WTH, yet the lowest soil exchangeable supplies, whereas the Washington sites had by far the highest base cation leaching and soil exchangeable supplies, yet only relatively moderate base cation exports via WTH. Sulfate was a major anion in soil solutions from the eastern sites, but total leaching rates were much lower than at Washington. Some eastern sites showed a net annual accumulation of base cations from atmospheric deposition. Some southeastern sites with Ultisols showed net retention of SO_4, but sites in the Tennessee Valley showed surprisingly little SO_4 retention.

344. **Johnson, Dale W.; Hornbeck, J. W.; Kelly, J. M.; Swank, W. T.; Todd, D. E. 1980.** Regional patterns of soil sulfate accumulation: relevance to ecosystem sulfur budgets. In: Shriner, D. S.; Richmond, C. R.; Lindberg, S. E., eds. Potential environmental and health consequences of atmospheric sulfur deposition: Proceedings of the 2d life science symposium; 1979 October 14-18; Gatlinburg, TN. Ann Arbor, MI: Ann Arbor Science Publications, Incorporated: 507-520.

Analyses of soils from Walker Branch, Camp Branch, and Cross Creek in Tennessee; from Coweeta in North Carolina; and Hubbard Brook in New Hampshire, support the hypothesis that watershed sulfur accumulation is due to inorganic sulfate adsorption in soils. Analyses of soils from lysimeter study sites at La Selva, Costa Rica, and Thompson site, Washington, produced similar results. In laboratory adsorption studies, only soils from Coweeta retained substantial (50 to 100 percent) additional amounts of sulfate in insoluble forms. Soil-adsorbed sulfate content and sulfate-adsorption capacity were positively correlated with free iron content but negatively correlated with organic matter content. Organic matter apparently blocks adsorption sites, preventing sulfate adsorption in iron-rich A horizons and Spodosol B2ir horizons. This blockage may account for the accumulation of adsorbed sulfate in B horizons in temperate and tropical soils and the susceptibility of New England Spodosols to leaching by H_2SO_4.

345. **Johnson, Dale W.; Kelly, J. M.; Swank, W. T.; Cole, Dale W.; Hornbeck, James W.; Pierce, Robert S.; and Van Lear, David. 1985.** A comparative evaluation of the effects of acid precipitation, natural acid production, and harvesting on cation removal from forests. ORNL/TM 9706. Oak Ridge, TN: Oak Ridge National Laboratory. 107 p. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

A comparison was made of the effects of acid deposition, natural leaching, and harvesting on base cation export from coniferous forests in Maine, coniferous and deciduous forests in Tennessee, a coniferous forest in South Carolina, a deciduous forest in North Carolina, and coniferous and deciduous forests in Washington. Sulfate dominated leaching in the Tennessee sites, whereas HCO_3 dominated leaching in the Maine, North Carolina, South Carolina, and Washington sites. Total base cation export by leaching exceeded Ca + Mg + K export that results from whole-harvesting in most sites. Some sites showed a net Ca or K accumulation from atmospheric deposition until whole-tree harvesting. However, leaching, even as augmented by acid deposition, does not appear to pose an imminent threat to soil base cation supplies because reserves are very large relative to leaching rates.

346. **Johnson, Dale W.; Todd, D. E. 1983.** Relationships among iron, aluminum, carbon, and sulfate in a variety of forest soils. Soil Science Society of America Journal. 47(4): 792-800.

Among several soil properties, percent Fe was the single parameter most closely related to SO_4 adsorption properties in a variety of forest soils. A combination of percentages of C, Fe, and Al appears most promising in predicting sulfate adsorption. Because organic matter had a decidedly negative influence upon SO_4 adsorption, surface soils and B horizons of Spodosols and highly podzolized soils had relatively poor SO_4 adsorption properties. Organic matter also reduced Fe crystallinity and the results of this study suggest that crystalline rather than amorphous, inorganic Fe is most highly correlated with adsorbed, water-insoluble SO_4.

347. **Johnson, Dale W.; Van Miegroet, Helga; Swank, Wayne T. 1989.** Markers of air pollution in forests: nutrient cycling. In: Biological markers of air-pollution stress and damage in forests. Washington, DC: National Academy Press: 133-142.

Air pollution may affect forest nutrient cycles in a number of ways, but many of these effects are difficult to evaluate because control sites unaffected by air pollution are seldom available for comparison. This paper summarizes the potential utility of using the following nutrient cycling

processes as markers of air pollution: nutrient content and flux in forest ecosystems; decomposition; soil leaching rates; and stream water-chemistry.

348. **Johnson, E. A. 1949.** Watershed studies producing valuable information. Outdoor News Bulletin. 3(11): 4.

Research at Coweeta to determine the influence of management practices on streamflow is briefly discussed.

349. **Johnson, E. A. 1952.** Effect of farm woodland grazing on watershed values in the Southern Appalachian Mountains. Journal of Forestry. 50: 109-113.

The effects of 11 years of grazing cattle on a forested Appalachian watershed are reported. The experiment is described; the effects of grazing on vegetation, soil, and water are presented; and practical implications of grazing mountain watersheds are discussed.

350. **Johnson, E. A.; Kovner, J. L. 1954.** Increasing water yield by cutting forest vegetation. Georgia Mineral Newsletter. 7(4): 145-148.

The authors report on changes in water yield at Coweeta after several different forest treatments.

351. **Johnson, E. A.; Meginnis, H. G. 1960.** Effect of altering forest vegetation on low flows of small streams. In: 12th general assembly International Union of Geodesy and Geophysics, International Association of Scientific Hydrology; 1960 July 25 - August 6; Helsinki, Finland. Publication 51. Washington, DC: International Association of Scientific Hydrology: 257-266.

Large increases in low flows were recorded after mountain hardwood stands were cut on controlled watersheds in North Carolina, and appreciable decreases in flow were recorded after pines were planted on a small Ohio watershed.

352. **Johnson, Edward A.; Dils, Robert E. 1956.** Outline for compiling precipitation, runoff, and ground water data from small watersheds. Stn. Pap. 68. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 40 p.

Procedures used at the Coweeta Hydrologic Laboratory for systematic compilation of data for continuous records of precipitation and stream discharges are described.

353. **Johnson, Edward A.; Kovner, Jacob L. 1956.** Effect on streamflow of cutting a forest understory. Forest Science. 2: 82-91.

On Coweeta Watershed 19, the laurel and rhododendron understory (22 percent of total basal area) was cut between December 1948 and March 1949. A 4-inch increase in water yield was achieved the first year after treatment, and the yield increase declined during the next 6 years. This increase was almost evenly divided between the growing and dormant seasons.

354. **Johnson, Philip L.; Swank, Wayne T. 1973.** Studies on cation budgets in the Southern Appalachians on four experimental watersheds with contrasting vegetation. Ecology. 54: 70-80.

Concentrations and flux of cations moving through a hardwood forest stand, a weed to forest succession, a hardwood coppice stand, and an eastern white pine stand on steep mountain topography are compared. Although concentrations for Ca, Mg, K and Na combined were usually <3.5 ppm, over 98 percent of the loss of each cation was in dissolved form. Regression analysis showed that 50 to 60 percent of the variation in monthly weighted average concentration was accounted for by monthly discharge amounts. Annual losses of four cations from the mature hardwood stand were in the amounts of approximately 7, 3, 5, and 10 kg/ha for Ca, Mg, K, and Na, with net budgets of -0.8, -1.8, -2.0, and -4.3 kg/ha. For Ca, the weed stand lost significantly greater amounts, while the young pine and hardwood coppice showed a net gain. All had significantly lower losses than the mature ecosystem for the other three ions. These budgets show that major alterations to these forest ecosystems are not now producing a substantial out-flux for cations.

355. **Keller, H. M. 1988.** European experiences in long-term forest hydrology research. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 407-414.

Long-term basin studies do not just happen. The time and the conditions of the economic and political situation, as well as the standing of the scientific community, need to mature to start such costly operations on a long-term basis. In this report, historic review will be combined with activities and experience in this field of research and interpretation of the past 100 years in Europe. Many of our forest watershed studies have been established based on the hypothesis that climate and the large-scale environment change only very slowly, and for practical purposes these parameters can be regarded as constant. However, the recent past has shown that these assumptions do not hold true anymore.

356. **Kenney, Nathaniel T. 1956.** Our green treasury, our national forests. National Geographic Magazine 110(3): 287-324.

Coweeta is featured in this popular review of the National Forest program. The color photo of Watershed 17 shows Coweeta employees Jake Kovner, Jack Shope and Bill Shope. Text highlights the mountain farm, woodland grazing, and exploitive logging demonstrations.

357. **Kirby, J. M.; Webster, J. R.; Benfield, E. F. 1983.** The role of shredders in detrital dynamics of permanent and temporary streams. In: Fontaine, Thomas D., III; Bartell, Steven M. Dynamics of lotic ecosystems. Ann Arbor, MI: Ann Arbor Science Publishers: 425-435.

Leaf-shredding insects may have an important role in breakdown of leaf detritus and the production of particulate organic matter (POM) in streams. This role was evaluated by comparing detrital dynamics in three

permanent and three temporary tributaries of Guys Run, Rockbridge County, Virginia. In general, the streams with fastest leaf breakdown, highest low-flow POM concentrations, and largest average POM particle sizes were found to have the greatest shredder and total insect densities. It was concluded that this is further evidence for the importance of shredders in woodland streams.

358. **Knipling, Edward B. 1967.** Effect of leaf aging on water deficit–water potential relationships of dogwood leaves growing in two environments. Physiologia Plantarum. 20: 65-72.

The relationships between water deficit and water potential were not the same for dogwood leaves of different ages or for leaves of the same age but growing in different environments. With leaf aging, particularly under high light intensity and dry environmental conditions, the relationships shifted to progessively lower water potentials for a given water deficit, increased dry weight, decreased cell-wall elasticity, and decreased osmotic potentials. The lack of constancy in the relationships reduces the usefulness of water deficit or relative turgidity as an estimator of water potential.

359. **Knipling, Edward B. 1967.** Measurement of leaf water potential by the dye method. Ecology. 48: 1038-1041.

The dye method for measuring leaf water potential is simple, inexpensive, and suitable for both laboratory and field work. Leaves are immersed in a graded series of solutions, and the solution which neither gains nor loses water is assumed to have a water potential equal to that of the leaf.

360. **Knipling, Edward B.; Kramer, Paul J. 1967.** Comparison of the dye method with the thermocouple psychrometer for measuring leaf water potentials. Plant Physiology. 42: 1315-1320.

The dye method for measuring water potential was compared with the thermocouple psychrometer method and found to be useful for measuring leaf water potentials of forest trees and common laboratory plants.

361. **Knoepp, Jennifer D.; Swank, Wayne T. 1993.** Site preparation burning to improve southern Appalachian pine–hardwood stands: nitrogen responses in soil, soil water, and streams. Canadian Journal of Forest Research. 23: 2263-2270.

Three paired watersheds treated with a fell-and-burn prescription were studied to determine the effects on soil, soil water, and stream-water nitrogen. Soil nitrification and mineralization were measured by closed core in situ incubation. Soil water was collected with porous-cup lysimeters placed at 30- and 60-cm depths, and water samples were collected from streams draining control and burned areas on one of the three sites. Data were collected for 6 months prior to and 12 months after treatment. Soil ammonium concentrations increased significantly in all three sites after burning, but the magnitude differed greatly among sites. However, there was no change in soil nitrate content. Net mineralization rates increased with increasing burn severity. Net nitrification displayed no treatment response. Slight and nonsignificant increases in soil water nitrate concentration occurred after burning in two of the three sites. Stream-water nitrate concentrations increased in the one stream sampled. Thus, while prescribed burning increased available soil N, there was little change in N transformation rates or movement of dissolved inorganic N offsite during the first year after burning.

362. Knoepp, Jennifer Donaldson; Swank, Wayne T. 1994. Long-term soil chemistry changes in aggrading forest ecosystems. Soil Science Society of America Journal. 58: 325-331.

Identification of the processes regulating chemical changes in forest soils is essential for assessing potential long-term forest productivity. The litter layer and upper two mineral soil horizons (A and AB/BA) in two aggrading Southern Appalachian watersheds were sampled 20 years after an earlier sampling. Soils under a mixed-hardwood stand exhibited a small but significant decrease in soil pH over time. Extractable base cation content declined substantially in both mineral horizons. A white pine stand was planted in 1956 after hardwoods were clear-felled and sprouts recut for 15 years. Soil pH and base cation concentrations declined in the A horizon under the pine from 1970 to 1990. Cation content did not change significantly in the AB/BA horizon. Nutrient budgets were constructed using these soil and litter data plus existing data on weathering rates, forest productivity, and hydrologic fluxes and associated chemistry. Decreases in soil base cations and soil pH are attributed to leaching and to the sequestration of nutrients in biomass.

363. **Kohl, J. -G., reviewer. 1990.** Forest hydrology and ecology at Coweeta. Feldes Repertorium. 101: 11-12.

A review of the Coweeta Symposium volume.

364. **Kovner, J. L. 1957.** Evapotranspiration in forest stands of the Southern Appalachian Mountains. Bulletin of the Georgia Academy of Science. 15(3): 80-85.

The author presents a method of estimating evapotranspiration by the water balance equation P - Ro = Ev, where P = precipitation, Ro = streamflow, and Ev = evapotranspiration, and discusses the relationship between estimated evapotranspiration and elevation.

365. **Kovner, Jacob L. 1957.** Evapotranspiration and water yields following forest cutting and natural regrowth. Proceedings, Society of American Foresters; 1956; Memphis, TN. Washington, DC: Society of American Foresters: 106-110.

The effects on stream regimen of cutting and later regrowth of a hardwood forest in the Southern Appalachians are reported. Changes in stand density are compared with changes in streamflow and P - RO (precipitation minus runoff).

366. **Kovner, Jacob L.; Evans, Thomas C. 1954.** A method for determining the minimum duration of watershed experiments. Transactions, American Geophysical Union. 35: 608-612.

A simple graphic solution is described for approximating the length of time required to detect significant differences between treatments on experimental watersheds.

367. **Kuhlman, E. G. 1983.** Effects of hypovirulence in *Cryphonectria parasitica* and of secondary blight infections on dieback of American Chestnut trees. Phytopathology. 73: 1030-1034.

Compatible hypovirulent (H) isolates of *Cryphonectria parasitica* applied to either wounded or nonwounded chestnut blight cankers reduced dieback of American chestnut trees for 27 to 51 months after inoculation in comparison to dieback of wounded or nonwounded controls. Most control trees were killed back to the point of inoculation with virulent (V) isolates within 15 to 19 months after inoculation. Initially, H treatments of wounded cankers promoted healing at the inoculation point, but subsequently the treatments sometimes failed to stop girdling by naturally developing basal cankers or secondary infections at the inoculation point.

368. **Kuhlman, E. G.; Bhattacharyya, H. 1984.** Vegetative compatibility and hypovirulence conversion among naturally occurring isolates of *Cryphonectria parasitica*. Phytopathology. 74: 659-664.

Virulent (V) isolates of *Cryphonectria parasitica* were readily recovered from both sunken cankers and swollen superficial cankers on American chestnut trees. Hypovirulent (H) isolates of *C. parasitica* made up 38 percent of the population in 6 swollen superficial cankers on one isolated tree in Tennessee but were infrequently recovered from 9 sunken and 52 swollen superficial cankers from North Carolina, Virginia, and Italy. Susceptibility to conversion by 6 H isolates was present in 80 percent of the 93 isolates, but the H isolates occurred in only 4 of 41 cankers. When American chestnut saplings were inoculated with H isolates, 52 percent were live and healed over, 28 percent were live and infected, and 20 percent had dieback to the inoculation point in 27 to 29 months. Inoculation of saplings with V isolates resulted in 3 percent live and 97 percent with dieback.

369. **Kuhlman, E. G.; Bhattacharyya, H.; Nash, B. L.; Double, M. L.; MacDonald, W. L. 1984.** Identifying hypovirulent isolates of *Cryphonectria parasitica* with broad conversion capacity. Phytopathology. 74: 676-682.

When 118 virulent (V) and 27 hypovirulent (H) isolates of *Cryphonectria parasitica* were paired in culture, 95 percent of the V isolates were converted to the hypovirulent condition by at least one of the H isolates. The 118 V isolates in 54 vegetative compatibility (v-c) groups included representatives from West Virginia, North Carolina, Virginia, Tennessee, and Italy. The average conversion capacity of 27 H isolates was 15 percent and ranged from 0 to 41 percent. Conidial or mycelial slurries of 7, 15, and 27 H isolates converted 87 to 93 percent of 102 randomly-selected V isolates from North Carolina. All 102 V isolates were converted by at least one of the H isolate treatments. Conidia were as effective as mycelia in conversion. Conidial slurries of as few as four H isolates with broad conversion capacity have potential for biological control of chestnut blight on American chestnut.

370. **Larson, N. M.; Reeves, M. 1976.** Analytical analysis of soil-moisture and trace-contaminant transport. ORNL/NSF/EATC-12. Oak Ridge, TN: Oak Ridge National Laboratory, Ecology and Analysis of Trace Contaminants Program. 180 p. In cooperation with the National Science Foundation. [Available from National Technical Information Service, 5285 Rort Royal Road, Springfield, VA 27161.

The Darcy conservation equation was formulated for solution of moisture movement through soil. Development of formulation and FORTRAN implementation are given. Computed outflow versus time curve was compared with experimental data from Coweeta Soil Model III and previous simulation by finite element technique.

371. **Leininger, T. D.; Winner, W. E.; Alexander, S. A. 1990.** Root disease incidence in eastern white pine plantations with and without symptoms of ozone injury in the Coweeta Basin of North Carolina. Plant Disease. 47(8): 552-554.

A survey was conducted in the Coweeta Basin, Macon County, North Carolina, to determine the incidence of root diseases and their relatedness to ozone symptomatology in two eastern white pine (*Pinus strobus*) plantations. *Heterobasidion annosum* was isolated from <1 percent of root segments sampled in a stand without symptoms of ozone-caused foliar injury. No root pathogens were found in a stand with symptoms of ozone-caused foliar injury. No relation was found between injury caused by ozone and the incidence of root diseases in these stands.

372. **Leopold, Donald J.; Parker, George R. 1985.** Vegetation patterns on a Southern Appalachian watershed after successive clearcuts. Castanea. 50(3): 164-186.

Coweeta Watershed 13 was clearcut in 1939 and 1940 and again in 1962. No timber was removed. Present vegetation composition (woody and herbaceous), and tree species distributions are related to site characteristics. *Liriodendron tulipifera* had the highest basal area and importance value of all tree species; *Quercus prinus* had the highest density, *Acer rubrum* the highest frequency. Stand basal area 21 years after the second clearcut was over 80 percent of that before the first. *Kalmia latifolia* and *Rhododendron maximum* responded vigorously to clearcuts, and the herbaceous layer is rich. Mesic species, especially *Liriodendron tulipifera* and *Betula lenta* have increased tremendously in importance since the 1934 inventory prior to clearcut and chestnut blight. These species now occupy more of the watershed, and the watershed supports vegetation of a more mesic nature.

373. **Leopold, Donald J.; Parker, George R.; Swank, Wayne T. 1985.** Forest development after successive clearcuts in the Southern Appalachians. Forest Ecology and Management. 13: 83-120.

Coweeta Watershed 13 was clearcut in 1939 and 1940 and again in 1962. Forest inventories were made in 1934, 1948, 1952, 1962, 1969, 1977, and 1984. Density, basal area, and size-class distribution of stems before the initial clearcut and during various stages of regrowth, were determined. The even-aged, coppice forest of 1984 had a density and basal area of 2330 stems/ha and 20.83 m^2/ha compared with 1934 values of 2632 stems/ha and 25.01 m^2/ha. Importance values of mesic species have increased tremendously over 50 years due to regeneration and growth following past disturbances of clearcutting and chestnut blight. Importance values of *Acer rubrum*, *Quercus coccinea* and *Q. prinus* have increased moderately while importance values of *Castanea dentata*, *C. pumila*, *Pinus rigida*, *Quercus alba* and *Q. rubra* have decreased. The size-class distribution of stems is a negative exponential function.

374. **Lewis, Clifford E.; Harshbarger, Thomas J. 1976.** Shrub and herbaceous vegetation after 20 years of prescribed burning in the South Carolina Coastal Plain. Journal of Range Management. 29: 13-18.

Twenty years of prescribed burning at different seasons and different frequencies altered the condition of shrub and herbaceous vegetation in the South Carolina Lower Coastal Plain. The six treatments were annual winter, annual summer, periodic winter, periodic summer, and biennial summer burning, and a no-burn control. Ground cover increased with most burning treatments, and herbage yields increased with all treatments. Annual summer burning eliminated most shrubs but periodic summer, annual, and periodic winter treatments did not. The number and density of herbaceous species increased with burning, especially on the annual and biennial summer treatments. Most of these changes appear beneficial for wildlife or grazing.

375. **Lieberman, J. A.; Fletcher, P. W. 1947.** Further studies of the balanced water cycle on experimental watersheds. Transactions, American Geophysical Union. 28(3): 421-424.

Maintaining a chronological account or balance of the components of the water resource on a watershed is frequently valuable in hydrology studies. In this paper, a time period for studying this balance is described: the period between the times of maximum watershed storage at the end of each dormant season. Changes in ground-water storage are thus taken into account, and, by choosing the beginning and ending points of the year at times of field capacity, changes in water storage in the soil mass are minimized.

376. **Lieberman, J. A.; Hoover, M. D. 1948.** The effect of uncontrolled logging on stream turbidity. Water and Sewage Works. 95(7): 255-258.

Unrestricted logging of Watershed 10 at Coweeta affected soil erosion and stream turbidity. The authors stress the need for improvements in the design, location, and maintenance of roads and in logging methods.

377. **Lieberman, J. A.; Hoover, M. D. 1948.** Protecting quality of stream flow by better logging. Southern Lumberman. 177(2225): 236-240.

The authors report on the results of unrestricted logging on Watershed 10 at Coweeta and present suggestions for road location and maintenance and logging practices which will protect the soil and water resource.

378. **Lieberman, J. A.; Hoover, M. D. 1951.** Stream-flow frequency changes on Coweeta experimental watersheds. Transactions, American Geophysical Union. 32: 73-76.

Frequency distribution curves of mean daily discharge from treated and control watersheds at Coweeta are compared for the prior- and post-treatment periods. Conclusions are drawn about the effect of the treatments on the regimen of daily streamflow and about the practicability of using frequency distribution curves to show streamflow changes brought about by experimental land use treatments.

379. **Lieberman, Joseph A. 1947.** Water resource and watershed management research in the Southeast. American Waterworks Association Journal. 39(5): 443-454.

The facilities, research program, and research findings at Coweeta Hydrologic Laboratory are reviewed.

380. **Lindberg, E.; Turner, R.; Lovett, M. 1983.** Mechanisms of the flux of acidic compounds and heavy metals onto receptors in the environment. In: Acid precipitation - origins and effects: VDI - Berichte 500; 1983 June 7-9; Lindau, West Germany. Dusseldorf, West Germany: Verlag des Vereins Deutscher Ingenieure: 165-171.

The authors report results of investigations of dry and wet atmospheric deposition of H, Cd, Mn, Pb, and Zn to several forested areas in the Eastern United States, including Coweeta. The dry deposition of soluble metals on leaf surfaces was found to be significant. Their interaction with precipitation increases concentrations, which may augment their physiological effects, particularly during periods of light precipitation.

381. **Lindberg, S. E.; Turner, R. R. 1983.** Trace metals in rain at forested sites in the Eastern United States. In: Proceedings of the international conference on heavy metals in the environment; 1983 September 6-9; Heidelberg, West Germany. Edinburgh, Scotland: CEP Consultants, Ltd: 107-114.

Precipitation was collected intermittently between 1975 and 1982 as wetfall-only at four forested sites in the Southeastern United States and analyzed for Cd, Mn, Pb, and Zn. Mean concentrations at these rural sites were low. Significant temporal and spatial trends were observed: all

metal concentrations were higher during warm weather periods; concentrations of Cd and Pb decreased from 1976-1977 to 1980-1982; and for this later period Cd and Pb also exhibited significant differences in concentration among sites. Manganese exhibited no significant trends. Metal concentrations in rain are negatively correlated with rainfall amount. We estimate that in-cloud aerosol scavenging dominates the long-term total wet deposition of these elements, but it is more important for Pb than for Cd and Mn.

382. **Lindberg, S. E.; Turner, R. R. 1988.** Factors influencing atmospheric deposition, stream export, and landscape accumulation of trace metals in forested watersheds. Water, Air, and Soil Pollution. 39: 123-156.

Wet and dry deposition inputs and streamflow output of Cd, Mn, Pb, Zn, and Al were measured intermittently at four deciduous forested watersheds between 1976 and 1982. Atmospheric inputs to each site were similar, varying by factors of 1.1 to 2.2 for the different metals. Metal levels in precipitation indicate that these sites are representative of rural, continental areas with concentrations generally higher during summer. The concentrations of Cd and Pb in both wet and dry deposition decreased between the period 1976 to 1977 and 1981 to 1982. Dry deposition dominated the input of Mn and Al to each site, while wet deposition was the major input process for the other metals. On an annual basis, deposited Cd, Pb, and Zn are strongly retained in each watershed. Deposited Mn and Al are retained to a lesser degree and show a net loss from two sites. Metal export is controlled by stream Ph, organic carbon, bedrock geology, and hydrologic characteristics of each site.

383. **Lowe, Rex L.; Golladay, Stephen W.; Webster, Jackson R. 1986.** Periphyton response to nutrient manipulation in streams draining clearcut and forested watersheds. Journal of The North American Benthological Society. 5(3): 221-229.

Nutrient-releasing artificial substrata were deployed in streams draining clearcut and forested watersheds to evaluate resources potentially limiting to populations of benthic algae. N, P, and Ca were released singly and in combination in the two streams that differed primarily in light availability. Periphyton were harvested after 1- and 2-month exposure periods and analyzed for chlorophyll. The 2-month substrata were additionally analyzed for algal community structure. Algal periphyton in the clearcut stream accumulated more chlorophyll and biovolume than in the forested stream across all nutrient treatments. Light appears to limit algal accumulation in the forested stream, and some populations in the clearcut stream may be nutrient limited.

384. **Lugthart, G. John; Wallace, J. Bruce. 1992.** Effects of disturbance on benthic functional structure and production in mountain streams. Journal of the North American Benthological Society. 11(2): 138-164.

To assess the role of macrofauna consumers in organic matter dynamics of headwater streams, we applied seasonal insecticide treatments to a Southern Appalachian mountain stream and compared benthic community structure between this and two other streams. Production was estimated in the two major habitats: mixed cobble-gravel-sand substrate and bedrock outcrop. Using the proportional availability of the habitats in each stream, production over the entire stream was measured. Insecticide applications resulted in dramatic changes in the macrofaunal community. Annual habitat-weighted production in the treated stream decreased by 62 percent from year 1 to year 2, with insects contributing only 45 percent to total production. The changes in macrofaunal community structure and production observed in the insecticide-treated stream were much greater than between-year changes in the reference stream despite the occurrence of a record drought in year 2. Estimates of ingestion suggested that the major functional groups were ingesting a fairly large portion of available resources in the untreated streams; insecticide treatments resulted in much lower levels of resource ingestion.

385. **Lugthart, Garrit J.; Wallace, J. Bruce; Huryn, Alexander D. 1990.** Secondary production of chironomid communities in insecticide-treated and untreated headwater streams. Freshwater Biology. 24: 417-427.

Annual production on non-Tanypodinae chironomids in three first-order Appalachian Mountain streams during a no-treatment year ranged from 1366 to 3636 mg/m^2, while production of Tanypodinae chironomids ranged from 48 to 116 mg/m^2. Production/biomass ratios ranged between 19 and 23 for non-Tanypodinae and from 6 to 7 for Tanypodinae chironomids. Insecticide applications significantly lowered chironomid densities and biomass in the treated stream relative to the pretreatment year and reference stream. Annual production of non-Tanypodinae (703 mg/m^2) and Tanypodinae (32 mg/m^2) chironomids in the treated stream decreased by 64 percent and 67 percent. In the same year, production of non-Tanypodinae (2084 mg/m^2) increased by 34 percent and production of Tanypodinae (96 mg/m^2) by 57 percent in the reference stream.

386. **Luvall, J. C. 1988.** Using the TIMS to estimate evapotranspiration from a white pine forest. In: The 2d Forest Service remote sensing applications conference: Remote sensing for resource inventory, planning, and monitoring; 1988 April 11-15; National Space Technology Laboratories, MS; Slidell, LA. Falls Church, VA: American Society for Photogrammetry and Remote Sensing: 90-98. [Available from National Space Technology Laboratories, MS]

Remotely sensed forest canopy temperatures from the Thermal Infrared Multispectral Scanner (TIMS) were used to estimate evapotranspiration (ET) from a white pine forest at Coweeta. Concurrent, tower-based measurements of net and solar radiation, sensible and latent heat flux, vapor pressure deficits, wind, soil moisture, stomatal resistance, leaf area index, and canopy structure allowed the results from a surface temperature model and energy

balance techniques to be compared. Three TIMS missions were flown on September 7, 1986, after sunrise, at solar noon, and at sundown. Additional measurements of needle temperature were taken to verify TIMS canopy surface temperatures. Results indicate that forest canopy temperatures measured by the TIMS are comparable to needle thermocouple temperatures and that ET estimates using TIMS data compared well with ET rates estimates using energy balance techniques.

387. **McBrayer, J. F.; Ferris, J. M.; Metz, L. J.; Gist, C. S.; Cornaby, B. W.; Kitazawa, Y.; Kitazawa, T.; Wernz, J. G.; Krantz, G. W.; Jensen, H. 1977.** Decomposer invertebrate populations in U.S. forest biomes. Pedobiologia. 17: 89-96.

Understanding the composition, population dynamics, and activity of soil invertebrates is essential to understanding the dynamics of forest decomposition. Decomposition, as an ecosystem process, is effected by microflora and invertebrates in a synergistic manner. The microflora are capable of accomplishing decomposition in the absence of the invertebrate animals and typically are responsible for more than 90 percent of the CO_2 evolved in forest decomposition. The invertebrates stimulate microbial respiration by improvement of substrate through fragmentation, chemical changes, or regulation of growth. This paper reports on decomposer invertebrate work supported by the two forest biome projects of the U.S. International Biological Program and compares numbers of invertebrates among sites and relates population densities to site factors. Vertical migration cycles and interactions between mesofauna and microfauna were two corollaries apparent during these studies.

388. **McIsaac, G. F. 1990.** Apparent geographic and atmospheric influences on raindrop sizes and rainfall kinetic energy. Journal of Soil and Water Conservation. 45(6): 663-666.

Rainfall kinetic energy was calculated from average drop-size distributions measured at Coweeta and five other locations. Median raindrop diameters in North Carolina, New Jersey, and the Marshall Islands tended to be less than those observed in Panama, Indonesia, Washington, DC, and Zimbabwe. Calculated rainfall kinetic energies for New Jersey, the Marshall Islands, and North Carolina ranged from 5 percent to 28 percent less than that predicted by the universal soil loss equation rainfall energy term. Increasing the rainfall energy estimate by 7 percent for each 1000 m (3280 feet) of elevation above sea level is suggested to account for increased raindrop velocity under reduced atmospheric pressure. Additional research is recommended for geographic effects on raindrop sizes and raindrop detachment of soil.

389. **McMinn, J. W.; Swank, Wayne T.; McNabb, W. H. 1986.** Scrub oak stands in the Southeast. In: Ffolliott, Peter F.; Swank, Wayne T., eds. Potentials of noncommerical forest biomass for energy. Tech. Bull. 256. Tucson, AZ: University of Arizona, School of Renewable Natural Resources: 11-24.

The term "scrub oak" is used in a generic sense to denote oaks of little or no commerical value. Scrub oak stands are found in every physiographic province of the Southeast, but a concentration occurs on deep sands in the Upper Coastal Plain of Georgia and the Carolinas, and in western and central Florida. The extent of the scrub oak type is indicated by the sampling locations for the primary data in this paper.

390. **McMinn, Jane W.; Hewlett, John D. 1975.** First-year yield increase after forest cutting: an alternative model. Journal of Forestry. 73(10): 654-655.

Analysis of the biologic and hydrologic processes suggests a more logical and general nonlinear model than the simple linear one previously used. Predictions of water yield increase based on the alternative model agree with those of the earlier model for heavy reductions in stand density, but are also forced to be nonnegative for light reductions in stand density.

391. **McSwain, Michael R. 1977.** Baseline levels and seasonal variations of enteric bacteria in oligotrophic streams. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 555-578.

Naturally occurring populations of enteric bacteria fluctuated seasonally and diurnally in mountain streams. Measurements of enteric bacteria were correlated with stream turbidities and stream temperatures. Data suggested that seasonal cycles were caused by multiplication of enteric bacteria in bottom sediments and that multiplication was regulated by stream temperatures. Elevated levels of total and fecal coliforms during storms appeared more related to bottom sediment disturbances than to streambank flushing. In contrast, increases in fecal streptococcus counts during storms appeared more related to the washing of overhanging stream vegetation and streambank flushing.

392. **McSwain, Michael R.; Swank, Wayne T. 1977.** Fluctuations in naturally occurring populations of enteric bacteria in oligotrophic streams of western North Carolina. Res. Note SE-158. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 12 p.

In mountain streams of western North Carolina, naturally occurring populations of enteric bacteria fluctuated seasonally and diurnally. Seasonal fluctuations in total coliforms and fecal coliforms were apparently regulated by water temperature. Diurnal fluctuations in total coliforms were inversely related to daily cycles in streamflow. Total and fecal coliforms and fecal streptococci peaked during stormflows. These fluctuations complicate the assessment of water quality and should be considered in designs for stream sampling.

393. **McSwain, Michael R.; Watrous, Russel J.; Douglass, James E. 1974.** Improved methylthymol

blue procedure for automated sulfate determination. Analytical Chemistry. 46: 1329-1331.

Describes a methylthymol blue procedure which increases the sensitivity of sulfate determinations using automated equipment.

394. **Maier, C. A.; Teskey, R. O. 1992.** Internal and external control of net photosynthesis and stomatal conductance of mature eastern white pine (*Pinus strobus*). Canadian Journal of Forest Research. 22: 1387-1394.

Leaf gas exchange and water relations were monitored in the upper canopy of two 25-m-tall eastern white pine (*Pinus strobus* L.) trees over two consecutive growing seasons (1986 and 1987). Examination of the seasonal and diurnal patterns of net photosynthesis and leaf conductance showed that both internal and external (environmental) factors were controlling net photosynthesis and leaf conductance. Internal control was indicated by a rapid increase and then decrease in the photosynthetic capacity of 1-year-old foliage during the development and maturation of current-year foliage, which was independent of environmental conditions. Large differences in net photosynthesis were observed between growing seasons due to seasonal differences in soil water availability, as indexed by predawn xylem pressure potential. Water stress reduced the maximum rate of net photosynthesis and altered the response of net photosynthesis and leaf conductance to absolute humidity deficit.

395. **Malas, Diane M.; Wallace, J. Bruce. 1977.** Strategies for coexistence in three species of net-spinning caddisflies (Trichoptera) in second order southern Appalachian streams. Canadian Journal of Zoology. 55: 1829-1840.

Three species of net-spinning caddisflies, *Parapsyche cardis*, *Diplectrona modesta*, and *Dolophilodes distinctus* were studied. Larvae of *Dolophilodes* are found at the lowest current velocities followed by *Diplectrona*, then *Parapsyche*, which prefer the higher velocities. *Parapsyche* larvae are most abundant on upper surfaces of stones while *Diplectrona* and *Dolophilodes* are found primarily on undersides of stones. These distribution patterns are probably related to capture net-mesh dimensions which differ greatly for the three species, *Parapsyche* having the largest and *Dolophilodes* the smallest meshes. There are large differences between mesh-opening sizes of last-instar *Dolophilodes* and first- and second-instar *Diplectrona* larvae. However, based on mean particle-size measurements of foregut contents, there is no corresponding gap in particle sizes used for food. Dietary composition also varied between species. *Parapsyche* consumed primarily animal material while *Dolophilodes* and *Diplectrona* consumed mostly vascular plant and fine detritus fragments.

396. **Mann, L. K.; Johnson, D. W.; West, D. C.; Cole, D. W.; Hornbeck, J. W.; Martin, C. W.; Riekerk, H.; Smith, C. T.; Swank, W. T.; Tritton, L. M.; Van Lear, D. H. 1988.** Effects of whole-tree and stem-only clearcutting on postharvest hydrologic losses, nutrient capital, and regrowth. Forest Science. 34(2): 412-428.

Nutrient removal by sawlog or pulpwood harvest (SAW) and whole-tree harvesting (WTH) for 11 forest stands located throughout the United States was compared with previously published nutrient budgets. Results indicated potential net losses of Ca and K at most sites without harvest and net losses of N, P, K, and Ca with either SAW or WTH. Total stem biomass and nutrients were significantly correlated with total above-stump biomass, providing a means for estimating nutrient removals with WTH and SAW in commercial forests. In the 11 harvested stands, hydrologic losses of N, K, and Ca increased immediately after harvest, returning to levels on control areas within 3 years. Hydrologic losses are considered minor relative to harvest removals. The large difference in amounts of nutrients left on site in logging slash after SAW compared with WTH did not result in major differences in leaching or runoff at sites where comparisons were made.

397. **March, William J.; Wallace, James R.; Swift, Lloyd W., Jr. 1979.** An investigation into the effect of storm type on precipitation in a small mountain watershed. Water Resources Research. 15: 298-304.

A set of regression equations relating storm rainfall depth to watershed topography and storm type was derived for the high-density precipitation network at Coweeta Hydrologic Laboratory. The most general equation predicted storm amounts for an independent test group of gages with an average error of 0.38 cm (0.15 inches). Predictions for the air-mass or thunderstorm type had the greatest errors. The dependent variable was the ratio of rainfall at each gage site to rainfall at a base gage. Predictive variables were topographic slope, aspect, ground elevation at the gage site, and smoothed elevation.

398. **Mattson, K.G.; Swank, W.T. 1989.** Soil and detrital carbon dynamics following forest cutting in the Southern Appalachians. Biology and Fertility of Soils. 7: 247-253.

Soil-system CO_2 efflux and detrital C pools were measured in three hardwood watersheds in the Southern Appalachians. Forests on two of the watersheds were clearcut and allowed to naturally regenerate; logging residue was removed on one clearcut and was left in place on the other. The third watershed was an uncut reference watershed. There was no statistically significant difference in CO_2 efflux between the two types of residue treatments on the clearcuts; however, CO_2 effluxes from the clearcuts were 33 percent less than from the uncut watershed. No long-term (5- to 8-year) changes in soil C pools were apparent following forest cutting. Reductions in CO_2 efflux on the clearcuts appear to be due to fewer live roots and to slower rates of forest-floor decomposition. Cutting of these forests followed by regeneration does not appear to result in large net C transfers to the atmosphere, as has been generally assumed.

399. **Mattson, Kim G.; Swank, Wayne T.; Waide, Jack B. 1987.** Decomposition of woody debris in a regenerating, clearcut forest in the Southern Appalachians. Canadian Journal of Forest Research. 17: 712-721.

Mass losses were estimated for coarse and fine woody debris during the first 7 years following clearcutting of a mixed hardwood forest. Estimates were based on precut forest biomass, volume, density and mass of debris at year 1, and wood-density changes by year 6 and mass changes by year 7. Decay constants were relatively high compared with other studies. Mass loss occurred largely through wood-density decreases and bark fragmentation. CO_2-efflux estimates accounted for over 90 percent of the density loss and for two-thirds of the total debris mass loss. The remaining mass loss of total debris is a source of large, organic matter inputs to the forest floor via solution fluxes and fragmentation. Density loss varied by more than tenfold among tree species. Density loss rates were 40 percent higher in logs on the ground versus those off the ground, 100 percent higher in logs with observable fungi versus those without fungi, and 40 percent higher in logs that occurred on south and east aspects.

400. **Mayack, David T.; Bush, Parshall, B.; Neary, Daniel G.; Douglass, James E. 1982.** Impact of hexazinone on invertebrates after application to forested watersheds. Archives of Environmental Contamination and Toxicology. 11: 209-217.

The impact of the herbicide hexazinone was assessed on aquatic macrophytes, aquatic and terrestrial invertebrate communities within forested watersheds in the Georgia Piedmont. Four watersheds were treated and subsequently monitored for 8 months. Residue levels in terrestrial invertebrates were a maximum of two orders of magnitude greater than comparable levels (0.01 to 0.18 ppm) found in forest floor material. Aquatic organisms in a second-order perennial stream were exposed to intermittent concentrations of hexazinone (6 to 44 ppb). Hexazinone residues were generally not detected (<0.1 ppm) in aquatic invertebrates and macrophytes. No major alterations in species composition or diversity were detected in the aquatic macroinvertebrate community.

401. **Meginnis, H.G. 1956.** Forestry and water resource development in the South. The Forest Farmer. (116)2: 12-13; 28-32.

Water, soil, and timber is the tangible stuff out of which the South is forging its new economic order; and water has become the largest single raw material item of the region's mushrooming industries.

402. **Meginnis, H. G. 1959.** Increasing water yields by cutting forest vegetation. In: Woodlands and water-lysimeters: Symposium, International Union of Geodesy and Geophysics. International Association of Scientific Hydrology; 1959 September 8-13; Hannoversch-Munden, Germany. Publication 48. Gerdbrugge, Belgium: International Association of Scientific Hydrology: 59-68.

The author discusses volume and timing of yield increases produced by clearcutting with annual cutting of regrowth, clearcutting with coppice regrowth allowed, and clearcutting of understory vegetation. Despite indications afforded by these experiments, a more complete knowledge of water requirements of cover and of plant-soil-climatic factors that govern evapotranspiration is required before yield increases caused by cover manipulations can be predicted accurately.

403. **Meginnis, H. G. 1960.** Watershed management research–challenging career for young scientists. Ames Forester. 47: 20-24.

The author outlines present knowledge in the field of watershed management, needs for further research, and opportunities for specialists in many disciplines who might wish to enter this field.

404. **Merrick, Elliot T.; Johnson, E. A. 1952.** Mountain water. American Forests. 58(10): 30-32, 38.

Objectives of the research program at Coweeta and studies of stream temperature and interception are briefly discussed.

405. **Merritt, Richard W.; Wallace, J. Bruce. 1981.** Filter-feeding insects. Scientific American. 244(4): 132-136, 141-142, 144.

This article discusses the variety of mechanisms that filter-feeding insect larvae employ to capture and ingest their food. These larvae utilize organic material which would otherwise be transported downstream, playing an important role in the processing and storage of organic material in stream ecosystems.

406. **Meyer, J. L.; Tate, C. M.; Edwards, R. T.; Crocker, M. T. 1988.** The trophic significance of dissolved organic carbon in streams. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 269-278.

Disolved organic carbon (DOC) is an important energy resource in Coweeta streams. It is removed from the water column by the benthic community and provides a carbon source for benthic bacteria, whose production rates exceed primary production in these forested, headwater streams. Streamwater DOC changes with watershed disturbance and recovery. Leaching of buried organic matter in the streambed contributes to elevated DOC concentrations in interstitial water. The ultimate fate of DOC in the stream trophic structure is a topic of research, and benthic meiofauna may prove to be an important link between DOC-utilizing bacteria and benthic macroinvertebrates.

407. **Meyer, Judy L.; Edwards, Richard T.; Risley, Rebecca. 1987.** Bacterial growth on dissolved organic carbon from a blackwater river. Microbial Ecology. 13: 13-29.

Different nominal molecular weight (MW) fractions of disolved organic carbon (DOC) from a southeastern

blackwater river were concentrated by ultrafiltration and added to sieved river water to assess each fraction's ability to stimulate bacterial growth. Bacterial growth and amount of DOC used was greatest with the low MW enrichment and least with the intermediate MW enrichment. For comparison, the low MW fraction of DOC from a clearwater mountain stream at Coweeta, a boreal blackwater river, and leachate from water oak and willow leaves also stimulated more bacterial growth than did other fractions.

408. **Meyer, Judy L.; Johnson, Carol. 1983.** The influence of elevated nitrate concentration on rate of leaf decomposition in a stream. Freshwater Biology. 13: 177-183.

Leaf decomposition was compared in two Coweeta streams, one draining an undisturbed hardwood watershed (18) and one draining a successional watershed (6) subject to an insect outbreak. The successional watershed had elevated nitrate concentrations in the streamwater. Both black locust (*Robinia pseudoacacia*) and sweet birch (*Betula lenta*) leaf litter decomposed 2.8 times more rapidly in the stream with high nitrate concentrations. The more rapid decay rates appeared to be partly due to accelerated microbial processing in response to nitrate enrichment, because microbial biomass (as ATP) was higher in the nitrate-enriched stream. Nitrogen and phosphorus content of the litter at the same state of decay was the same in the two streams.

409. **Meyer, Judy L.; McDowell, William H.; Bott, Thomas L.; Elwood, Jerry W.; Ishizaki, Chanel; Melack, John M.; Peckarsky, Barbara L.; Peterson, Bruce J.; Rublee, Parke A. 1988.** Elemental dynamics in streams. Journal of the North American Benthological Society. 7: 410-432.

This review discusses elemental dynamics in streams and identifies critical gaps in understanding. Both landscape-level processes (e.g., geology, land-use practices, vegetation) and heterogeneous in-stream processes influence the supply and availability of elements to the stream biota. Stream ecologists need to consider the relative availability of different compounds to the biota rather than lumping all forms into operationally defined units such as dissolved organic nitrogen or carbon. The impact of short-term events like storms on elemental dynamics needs to be assessed and compared with other controls. The relative importance of upstream, riparian zone, floodplain, and in-stream controls of supply and availability of elements must be compared in a variety of streams. Availability of essential elements controls rates of primary productivity and decomposition in streams. Whole system manipulations are valuable tools for understanding interactions between elements and all components of the stream food web.

410. **Meyer, Judy L.; O'Hop, Joe. 1983.** Leaf-shredding insects as a source of dissolved organic carbon in a headwater stream. American Midland Naturalist. 109: 175-183.

We investigated the importance of leaf-shredding insects as generators of dissolved organic carbon (DOC) in a headwater stream. We fed three common shredders (*Peltoperla maria*, *Pteronarcys scotti*, and *Tipula* spp.) naturally conditioned leaves and measured the rates at which they generated DOC. Rates ranged from 0.2 to 160 μg C/mg ash-free dry weight per day, and 62 percent of this variation could be explained by organism weight. Less than 10 percent of DOC generated was produced by mechanical breakup of the leaves. DOC generated was predominantly of high (>10000 daltons) molecular weight. DOC released by shredders is a potentially significant source of DOC in headwater streams during low flow. Shredder feeding is potentially as important a source of DOC in small streams as leaching of leaf litter.

411. **Meyer, Judy L.; Tate, Cathy M. 1983.** The effects of watershed disturbance on dissolved organic carbon dynamics of a stream. Ecology. 64: 33-44.

The response of a stream ecosystem to watershed disturbance was investigated by comparing budgets of disolved organic carbon (DOC) for a stream draining an undisturbed watershed with a stream draining a watershed clearcut 2 years previously. Both streams had elevated DOC concentration during storms. In the undisturbed stream, DOC concentration increased from seep to weir during the growing season. DOC concentration and annual export from the clearcut watershed was less (9.8 to 11.5 kg/ha) than from the reference (14.6 to 15.1 kg/ha). Lower export was partly due to reduced DOC inputs from throughfall and leaching litter, but most importantly to lower DOC inputs in subsurface water and less instream generation of DOC. The rate of recovery of this stream from disturbance is dependent on the rate at which the terrestrial system recovers.

412. **Mitchell, John E.; Waide, Jack B.; Todd, Robert L. 1975.** A preliminary compartment model of the nitrogen cycle in a deciduous forest ecosystem. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symp. Ser. Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 41-52. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

A compartment model of nitrogen storage and transfer in a mature hardwood forest at Coweeta is described and discussed. Most of the nitrogen in this ecosystem is localized in large storage compartments that turn over slowly. Over 80 percent of the total nitrogen is in soil organic matter, with about 11 percent in vegetation, 3 percent in litter, 4 percent in microbes, and 2 percent in free soil pools. Uptake of nitrogen is estimated to be 141.6 kg/ha/yr, of which about 10 percent is retained within the vegetation. A large pool of nitrogen recycles annually within plants. Litter inputs to soil organic pools are dominated by belowground material, especially small roots and mycorrhizae. In the soil, available nitrogen seems

to be rapidly immobilized by soil biota or taken up by the root-mycorrhizae complex, with very little nitrogen being lost from the system in stream water or via denitrification. This study shows a dynamic cycle where nitrogen is retained and recycled within the ecosystem.

413. **Mitchell, M.J.; Harrison, R.B.; Fitzgerald, J.W.; Johnson, D.W.; Lindberg, S.E.; Zhang, Y.; Autry, A. 1992.** Sulfur distribution and cycling in forest ecosystems. In: Johnson, D.W.; Lindberg, S.E., eds. Atmospheric deposition and forest nutrient cycling: a synthesis of the Integrated Forest Study. Ecological Studies, vol. 91. New York: Springer-Verlag: 90-117.

Two sites at Coweeta, one in white pine and the other in mixed hardwood, were part of the Integrated Forest Study. Sulfur content was compared across a gradient of input rates. The mineral soil component of all sites contained, by far, the largest sulfur content (at Coweeta about half the soil pool was in the sulfate form). Sulfur pools in vegetation were larger at Coweeta than most other sites, with the nitrogen-sulfur ratio largest in foliage at the Coweeta hardwood site. The fluxes and factors regulating sulfur dynamics are compared across the various sites and contrasting vegetations.

414. **Monk, C. D.; Crossley, D. A., Jr.; Todd, R. L.; Swank, W. T.; Waide, J. B.; Webster, J. R. 1977.** An overview of nutrient cycling research at Coweeta Hydrologic Laboratory. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 35-50.

A research program at the Coweeta Hydrologic Laboratory, North Carolina, is investigating effects of manipulations on nutrient cycling and productivity of forested watersheds. The experimental approach is to explain whole ecosystem behavior, as revealed by watershed nutrient and water budgets, by reference to internal ecosystem processes. This report describes the general scope of the research at process levels, and relates dynamics of internal processes to ecosystem level response. The research is organized around a general theory of ecosystem relative stability, based on the complementary aspects of resistance to disturbance and resilience following disturbance.

415. **Monk, C. D.; Day, F. P., Jr. 1988.** Biomass, primary production, and selected nutrient budgets for an undisturbed hardwood watershed. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 151-159.

The forests of lower elevations (700 to 1000 m) in the Coweeta Basin are now dominated by several species of oaks. However, chestnut was the leading dominant prior to invasion by the blight. Mesic species (tulip, poplar, yellow birch, hemlock, witch-hazel, dogwood, and rhododendron) are positively correlated with distance from the water divide and aspect, and are negatively correlated with distance from the stream channel and elevation. Xeric species (chestnut oak, scarlet oak, pignut hickory, mountain laurel, sourwood, red maple, and black gum) bear the opposing correlations. Soil P for a single watershed at low elevation is quite low when compared with other elements and insufficiently available for uptake by many species. If P limits productivity, then it should be more limiting to the deciduous component than to the evergreen component. This may in part explain the extensive distribution of evergreen species in the Coweeta Basin and their competitive success in responding to past forest disturbances.

416. **Monk, C. D.; McGinty, D. T.; Day, F. P., Jr. 1985.** The ecological importance of *Kalmia latifolia* and *Rhododendron maximum* in the deciduous forest of the Southern Appalachians. Bulletin of the Torrey Botanical Club. 112(2): 187-193.

Mountain laurel and rosebay rhododendron comprise an important evergreen component in the deciduous forests of the Southern Appalachians. These evergreen, sclerophyllous shrubs are widely distributed over the landscape, with *Kalmia* associated with drier, more exposed sites and *Rhododendron* associated with more mesic sites. Dense stands of these two species may interfere with tree establishment and may contribute as much as 32 percent to the total standing crop of leaf biomass in some forests. Even though nutrient concentrations of their leaves are generally lower than that of deciduous trees, leaf longevity permits significant storage of nutrients. Resorption of N, P and K prior to leaf fall is an important nutrient flux.

417. **Monk, Carl D. 1971.** Species and area relationships in the eastern deciduous forest. Journal of the Elisha Mitchell Science Society. 87: 227-230.

The species curve derived from data within the eastern deciduous forest is a three-component curve. Species and area are linearly related to areas between 10^2 to 10^6 km^2 with a slope of approximately 0.25. The model that gives the best fit is a simple log-log regression equation. In large contiguous continental sites, area is a better estimator of the number of species than maximum elevation or elevation range. Since elevation and area are highly correlated, including both in multiple regression models does not improve the prediction of number of species.

418. **Monk, Carl D. 1975.** Nutrient losses in particulate form as weir pond sediments from four unit watersheds in the Southern Appalachians. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symp. Ser. Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 862-867. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Weir-pond sediments were collected at 3-month intervals for a period of 2 years from four watersheds with contrasting vegetation. Annual sediment losses for the four watersheds were 283 kg/ha from the coppice hardwoods,

176 kg/ha from the old field, 76 kg/ha from the pine plantation, and 30 kg/ha from the mature hardwoods. Greater losses occurred during the winter season. The composition of the sediments from the old field, coppice hardwoods, and pine plantations were similar. Nutrient concentrations varied from watershed to watershed and in some instances seasonally. Nutrient loss as weir-pond sediments accounts for no more than 1 percent of the total loss.

419. **Monk, Carl D.; Day, Frank P., Jr. 1985.** Vegetation analysis, primary production and selected nutrient budgets for a Southern Appalachian oak forest: a synthesis of IBP studies at Coweeta. Forest Ecology and Management. 10: 87-113.

The vegetation of lower slope (700-1000 m) positions in the Southern Appalachians is dominated by several species of oaks. These forests have attained pre-chestnut blight levels of basal area, but evidence of disturbance (chestnut blight, logging and drought) appears in age structure as more individuals established between 1918 and 1938. The forests contain 40 tree species whose spatial distribution patterns on slopes follow topographic moisture gradients. Total standing crop of biomass is 191332 kg/ha (roots 27 percent, stems 70 percent, leaves 3 percent). In these deciduous forests, evergreen species contribute 30 to 35 percent to leaf biomass. Some tree species are specifically important to nutrient cycling because of higher concentrations in certain tissues.

420. **Montagnini, F.; Haines, B. L.; Swank, W. T.; Waide, J. B. 1989.** Nitrification in undisturbed mixed hardwoods and manipulated forests in the southern Appalachian Mountains of North Carolina, U.S.A. Canadian Journal of Forest Research. 19: 1226-1234.

This paper summarizes data on nitrification and effects of watershed treatment and vegetation type. At Coweeta, as at other United States sites, oak-hickory forests gave the lowest nitrification potentials, and nitrification potentials and nitrifier numbers were higher in disturbed watersheds. Nitrification potentials were low in a white pine plantation, although higher than in other pine forests in the United States. In a regenerating clearcut and in a 17-year-old successional forest at Coweeta, nitrification potential was elevated in dense stands of black locust (*Robinia pseudoacacia* L.). In the undisturbed forests, low nutrient availability probably limits the size of nitrifier populations; the influence of soil pH on nitrification was unclear. In the disturbed forests, nitrification is apparently controlled by the availability of ammonium nitrogen and other nutrients.

421. **Montagnini, Florencia; Haines, Bruce; Boring, Lindsay; Swank, Wayne. 1986.** Nitrification potentials in early successional black locust and in mixed hardwood forest stands in the Southern Appalachians, USA. Biogeochemistry. 2: 197-210.

Soil nitrogen mineralization and nitrification potentials, and soil solution chemistry were measured in black locust, in pine–mixed-hardwood stands on an early successional watershed, and in an older growth oak-hickory forest located on an adjacent, mixed hardwood watershed at Coweeta. Nitrification potentials were higher in black locust and pine-mixed hardwood early successional stands than in the oak-hickory forest of the older growth watershed. Ammonification rates were the main factor controlling nitrification in the early successional stands. There was no evidence of inhibition of nitrification in soils from the older growth oak-hickory forest site.

422. **Montagnini, Florencia; Haines, Bruce; Swank, Wayne. 1989.** Factors controlling nitrification in soils of early successional and oak/hickory forests in the Southern Appalachians. Forest Ecology and Management. 26: 77-94.

Factors regulating nitrification were examined in three forests of contrasting nitrifying activity in the Southern Appalachians. NH_4-N availability was the main factor regulating nitrification in early successional forests dominated by pine–mixed-hardwood and black locust. Litter leachate solutions from black locust had high concentrations of N and other nutrients, but their influence upon nitrification was relatively small. In a mature oak-hickory forest, nitrification was not stimulated by NH_4-N amendments, nor by amendments of black locust litter leachate solutions. Amendments with $CaCO_3$ and $CaCl_2$ stimulated ammonification but not nitrification. Oak leaves may inhibit nitrification. Low nitrification was also found in glucose-amended laboratory incubations of black locust soils, suggesting that an increase of the C:N ratio of the soil could be responsible for low nitrification rates.

423. **Montagnini, Florencia; Haines, Bruce; Swank, Wayne T. 1991.** Soil-solution chemistry in black locust, pine/mixed-hardwoods and oak/hickory forest stands in the southern Appalachians, U.S.A. Forest Ecology and Management. 40: 199-208.

Soil-solution chemistry was measured over a 15-month period in three forest stands of contrasting nitrogen mineralization and nitrification rates, using porous-cup lysimeters. In a stand dominated by black locust, soil solution NO_3-N was two orders of magnitude greater than in a pine–mixed-hardwood stand. Dissolved organic N (DON) was threefold greater. At both depths, soil solution conductivity, pH, Ca, Mg, K, and PO_4-P were higher in black locust than in pine–mixed-hardwoods, and there were no differences in soil solution Na. In an oak-hickory stand, soil solution NO_3-N at 30-cm depth was much less than in the other stands, while DON was half that of the black locust. At 30-cm depth, soil-solution conductivity, Ca, Mg and PO_4-P were higher in black locust than in oak-hickory, with no differences in pH, K and Na. In the oak-hickory and pine–mixed-hardwoods forest stands, with relatively lower soil N turnover rates, DON was a major portion of soil solution N.

424. **Moore, Allen; Swank, Wayne T. 1975.** A model of water content and evaporation for hardwood leaf litter. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symp. Ser.

Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 58-69. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

A predictive model of water content and evaporative losses in the litter of a mixed deciduous forest is presented. The model uses readily obtainable data on total daily incoming solar radiation, rainfall, mean daytime temperature, and mean daytime relative humidity. The model also requires data on site latitude, slope and aspect; initial litter accumulation; annual quantity and timing of leaf fall; and transmission of solar radiation through the canopy. The model incorporates throughfall and litter decay functions. Model performance was tested against independent data collected over 8- to 11-day periods in summer and winter seasons and agreed within 13 percent of estimated evaporation. Daily values of litter water content were usually within the error limits of experimental data. Predicted evaporation and litter water content over an 80-day period also showed good agreement with experimental data.

425. **Mueller, E. A.; Sims, A. L. 1967.** Raindrop distibutions at Franklin, North Carolina. Fort Monmouth, NJ: U.S. Army Electronics Command, Atmospheric Sciences Laboratory. technical report; ECOM-02071-RR3. 165 p.

Raindrop-size distributions for 4742 samples of 1 m^3 each were obtained from a drop camera near Mooney Gap at Coweeta, from December 21, 1960 through March 25, 1962. For each of the samples, rainfall rate, radar reflectivity, liquid water content, attenuation crosssection, median volume diameter, and the total number of drops were calculated from the distribution. Average distributions for various rainfall rates and radar reflectivities are given.

426. **Mueller, E. A.; Sims, A. L.; Cataneo, R. 1967.** Investigation of the quantitative determination of precipitation by radar. Fort Monmouth, NJ: U.S. Army Electronics Command. Atmospheric Sciences Laboratory. technical report; ECOM-02071-1. 58 p.

Rainfall drop-size distributions measured by Illinois State Water Survey drop camera at Coweeta Hydrologic Laboratory and four other sites in Eastern and Western United States were analyzed to define attenuation of weather radar at the 75-mile range. Drop-size distributions from Coweeta and New Jersey were similar, but both were different from Arizona data.

427. **Munn, Nancy L.; Meyer, Judy L. 1988.** Rapid flow through the sediments of a headwater stream in the southern Appalachians. Freshwater Biology. 20: 235-240.

Underflow may be a major component in the functioning of Appalachian mountain streams. The flow of water through the sediment layer of streams can influence nutrient uptake dynamics and the supply of materials to microbes, meiofauna and macroinvertebrates living within stream sediments. The extent of underflow in Hugh White Creek, a headwater stream in the Southern Appalachian Mountains, was examined at different depths and at different sites within the stream. Chloride was a more suitable tracer than rhodamine dye. The tracer infiltrated the sediments within 5 minutes to depths of 10 cm at all six sites. Infiltration tended to decrease with depth of sediments at all sites although there was no consistent statistical pattern. Equilibrium between the water column and sediments was reached within minutes for sites with coarse sediments and within a few hours for sites with finer sediments.

428. **Munns, Edward N. 1947.** Forest hydrology in the Appalachians. Journal of Soil and Water Conservation. 2: 71-76.

Forests have beneficial effects on regulating streamflow, as opposed to other forms of land management. Watershed experiments at Coweeta are discussed.

429. **Munns, Edward N. 1948.** Our forests and watersheds. Scientific Monthly. 67(5): 347-354.

The research facilities, program, and findings at Coweeta Hydrologic Laboratory are summarized.

430. **Murphy, Charles E., Jr.; Knoerr, Kenneth R. 1975.** The evaporation of intercepted rainfall from a forest stand: an analysis by simulation. Water Resources Research. 11(2): 273-280.

A model of the energy exchange between the atmosphere and a vegetated surface has been developed and used to investigate the sources of energy available for evaporation of precipitation intercepted by a forest canopy. Simulations with this model have demonstrated that a forest canopy wetted by rainfall will partition more of the absorbed radiant energy into latent heat exchange than an unwetted canopy in the same environment. This energy diversion creates a decrease in sensible heat transfer from the canopy to the atmosphere and a smaller decrease in a long-wave radiation emitted by the canopy.

431. **Neary, D. G. 1988.** Effects of pesticide applications on forested watersheds. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 325-337.

The objective of this chapter is to highlight current knowledge of the effects of pesticide application on biological and hydrological processes in Southern Appalachian forest watersheds. Although Coweeta has not emphasized research on the impact of pesticides, information about the physical, chemical, and biological effects has been obtained in the past 20 years from studies using herbicides or insecticides to achieve some other objective. Insecticides have been applied to regulate outbreaks of terrestrial insects and to study instream detritus processing dynamics of aquatic insects. Some of the original research on the effects of forest treatments on water yield used herbicides to simulate cutting or induce

vegetation succession. More recently, a series of studies have determined the impact of site preparation herbicides on water quality.

432. **Neary, D. G.; Bush, P. B.; Douglass, J. E. 1981.** 2, 4, and 14-month efficacy of hexazinone for site preparation. In: Proceedings of the Southern Weed Science Society; 1981 January 20-22. Champaign, IL: Southern Weed Science Society: 181-191. Vol. 34.

Hexazinone pellets were applied at 1.68 kg/ha active ingredient to kill hardwoods in 60- to 80-year-old mixed hardwood-pine stand in the upper Piedmont of Georgia. Herbicidal effects on vegetation were observed within 2 weeks of the first rain, and defoliation of the hardwood canopy started 1 month later. Two months after the hexazinone application most oaks were severely affected. Four months after treatment, 63 to 91 percent of the oaks were completely defoliated. After 14 months, 83 to 96 percent of all oaks were killed, and most other hardwoods suffered heavy mortality. Mortality among residual pine stems were affected to some degree (5 to 15 percent).

433. **Neary, D. G.; Bush, P. B.; Douglass, J. E.; Todd, R. L. 1985.** Picloram movement in an Appalachian hardwood forest watershed. Journal of Environmental Quality. 14: 585-592.

Picloram was applied at a rate of 5.0 kg/ha acid equivalent to 4 ha of a 28-ha watershed on Coweeta. Herbicide was broadcast manually as pellets to eliminate a poor-quality mixed oak overstory and rhododendron-laurel understory prior to planting white pine. Picloram residues in soil samples peaked in concentration in the upper 0.07 m, had a half-life of about 4 weeks, and declined to near detection limits 28 weeks after application. Soil solution contained the highest picloram levels at 0.6 m. Picloram residues were detected in soil solution 1.2 m into the soil, but concentrations were <25 mg/m^3, and persisted for only 60 weeks. Intensive sampling of two springs detected trace levels for a period of 8 days. Only sporadic, low-level picloram residues were detected in streamflow from nested 10-ha and 28-ha watersheds during a 70-week period. Use of the herbicide picloram did not affect the quality of streamflow from Watershed 19 for domestic or agricultural purposes.

434. **Neary, D. G.; Bush, P. B.; Grant, M. A. 1986.** Water quality of ephemeral forest streams after site preparation with the herbicide hexazinone. Forest Ecology and Management. 14: 23-40.

Four small watersheds were treated with 1.68 kg/ha active ingredient of hexazinone pellets. Residues in stormflow peaked in the first storm, declined rapidly thereafter, and disappeared within 7 months. Loss of hexazinone in stormflow averaged 0.53 percent of the applied herbicide. Suspended solid concentrations in runoff from the treated watersheds were slightly more than those of the control. Total sediment yields were increased by a factor of 2.5 due to increased runoff associated with site preparation using herbicide and salvage logging. However, sediment loadings remained below those produced by mechanical techniques and well within levels common in relatively undisturbed forests. Hexazinone treatment produced a large increase in NO_3-N concentrations, which returned to normal within 2 years. Hexazinone may have stimulated nitrifying bacteria. Cation concentrations temporarily increased 30 to 100 percent as a result of hexazinone application. Overall, water quality changes were small and short-lived.

435. **Neary, D. G.; Comerford, N. B.; Swift, L. W., Jr. 1993.** Land and riparian interactions with sediment in the Southern United States. In: Proceedings, technical workshop on sediments; 1992 February 3-7; Corvallis, OR. Washington, DC: Terrene Institute: 51-60.

This review compares forestry-caused sedimentation rates with other human causes and focuses on the buffer zone as a management tool to mitigate sediment damage to streams. A comprehensive literature review leads to four proposed science questions and a statement of research needs.

436. **Neary, D. G.; Douglass, J. E.; Fox, Walter. 1979.** Low picloram concentrations in streamflow resulting from application of Tordon 10K. In: Proceedings of the Southern Weed Science Society; 1979 January 23-25; Atlanta, GA. Auburn, AL: Auburn University Printing Service: 182-197. vol. 32.

Picloram pellets were applied to Watershed 19 at the Coweeta Hydrologic Laboratory to prepare a low-quality hardwood stand for planting eastern white pine. The herbicide was applied in May 1978 at a rate of 50 kg/ha active ingredient. Despite dry weather, 76 percent of the overstory plants and 95 percent of the rhododendron and laurel in the understory were initially affected. During the first 5 months after application, soil solution at 30-cm depth contained less than 10 ppb picloram until heavy rains in August; then, a peak of 174 ppb was measured. At 60-cm depth, picloram peaked at 179 ppb. At 120-cm depth, picloram never exceeded 3 ppb. Picloram was detected only twice in streamflow (maximum concentration 8 ppb).

437. **Neary, D. G.; Swank, W. T.; Riekerk, H. 1989.** An overview of nonpoint source pollution in the Southern United States. In: Hook, Donal D.; Lea, Russ, eds. Proceedings of the symposium: The forested wetlands of the Southern United States; 1988 July 12-14; Orlando, FL. Gen. Tech. Rep. SE-50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 1-7.

This paper examines nonpoint source pollution (NPSP) in the 13 States of the Southern Region. The definitions, sources, types, and trends of NPSP is of particular concern to wetlands because it is difficult to manage and most States have little knowledge of the effects on wetlands. Information is very limited on the cumulative effects of different NPSP sources on wetlands. Where water quality is deteriorating, NPSP is frequently the major cause. Best management practices implemented by local and State agencies provide the best means of controlling NPSP.

438. **Neary, D. G.; Swift, L. W., Jr. 1987.** Rainfall thresholds for triggering a debris avalanching event in the southern Appalachian Mountains. In: Costa, John E.; Wieczorek, Gerald F., eds. Debris flows/avalanches: process, recognition, and mitigation: Proceedings of the Engineering Geology and Quaternary Geology and Geomorphology Division of the Geological Society of America; 1984 November 5; Reno, NV. Reviews in Engineering Geology. Boulder, CO: The Geology Society of America: 81-92. Vol. 7.

In November 1977, a storm system produced intense rainfall that set off debris avalanching in steep terrain of the Pisgah National Forest, North Carolina. All the classical conditions of above-normal antecedent moisture, heavy rainfall followed by intense downpours, steep slopes, and shallow soils were present. Peak hourly rainfall intensities of 90 to 100 mm/hr approach the suggested 24-hour threshold for initiating debris avalanches in mountainous regions and were the key to triggering these slope failures in well-drained and highly permeable forest soils of the Southern Appalachians. Long-return periods of 100 to more than 200 year for destructive events obscure the perception of their importance as an erosional process. Although slope stability is not recognized as a general problem in mountainous areas of the East, debris avalanching is a major contributor to long-term erosion rates and influences formation of some of the more productive forest soils.

439. **Neary, D.G.; Swift, L.W., Jr.; Manning, D.M.; Burns, R.G. 1986.** Debris avalanching in the Southern Appalachians: an influence on forest soil formation. Soil Science Society of America Journal. 50: 465-471.

In early November 1977, a storm system formed in the Gulf of Mexico and moved northeast into the Appalachian Mountains. It produced intense, heavy rainfall which triggered debris avalanching in steep terrain of the Pisgah National Forest. Soil material displaced by the mass wasting was about 2 to 3 10^3/ha along avalanche tracks, which exceeded 1 km in length. Peak stormflows had recurrence intervals ranging from 20 to >100 year. Factors prominent in development of the storm were evaluated using infrared satellite imagery and rain data. Most debris avalanches on one well-documented basin originated in shallow soils on upper slopes and ran out onto lower gradient deposition zones. Although debris avalanching in the Appalachian Mountains is a rare phenomenon in human history (100 to 1000+ year return period), it is a major and frequent geomorphic process influencing soil formation.

440. **Neary, Daniel G. 1983.** Monitoring herbicide residues in springflow after an operational application of hexazinone. Southern Journal of Applied Forestry. 7(4): 217-223.

Parts of two forested watersheds (440 and 482 acres) in central Tennessee were aerially treated with 15 pounds per acre of hexazinone pellets (10 percent active ingredient) to remove hardwood competition prior to establishing loblolly pine (*Pinus taeda* L.). Both treated watersheds and a control were monitored to determine if hexazinone residues were entering ground water and appearing in springflow. Seven months of monitoring included two intensively sampled periods during application and the first storm. No detectable residues of hexazinone or its two primary metabolites were measured in samples from a watershed in which hexazinone was applied up to 66 feet from the monitoring point. Springflow samples from a watershed treated a year earlier were also clear of herbicide residues.

441. **Neary, Daniel G.; Bush, Parshall B.; Douglass, James E. 1983.** Off-site movement of hexazinone in stormflow and baseflow from forest watersheds. Weed Science. 31: 543-551.

Four forest watersheds in the upper Piedmont of Georgia were treated with hexazinone pellets at a rate of 1.68 kg/ha active ingredient. Twenty-six storms were monitored to determine movement of hexazinone and two of its metabolites in runoff. Residues peaked in the first storm after application (442 $\pm$ 53 ppb), and declined with subsequent storms in a power curve function. Loss of hexazinone averaged 0.53 percent of the applied herbicide, with two storms accounting for 59.3 percent of the chemical exported. Subsurface movement of hexazinone appeared in streamflow 3 to 4 months after application and produced an additional loss of 0.05 percent.

442. **Neary, Daniel G.; Currier, John B. 1982.** Impact of wildfire and watershed restoration on water quality in South Carolina's Blue Ridge Mountains. Southern Journal of Applied Forestry. 6: 81-90.

Streams in the Blue Ridge Mountains of South Carolina were monitored after the 1978 Jumping Branch Wildfire. Differences in NO_3-N, NH_4-N, PO_4-P, Na, K, Ca, and Mg concentrations were attributed to the fire or watershed restoration. Concentrations of NO_3-N increased the most (peak of 0.394 mg/L), primarily as a result of fertilizer application during restoration operations. Ammonium nitrogen, NO_3-N, and PO_4-P levels were elevated on burned and fertilized watersheds mainly during storm events. Cation concentrations were 12 to 82 percent above background levels during the monitoring. Suspended solids showed no relationship to watershed condition. Changes in water quality did not reduce the value of the streams as a source of drinking water or affect aquatic ecosystem stability.

443. **Neary, Daniel G.; Douglass, James E.; Ruehle, John L.; Fox, Walter. 1984.** Converting rhododendron-laurel thickets to white pine with picloram and mycorrhizae-inoculated seedlings. Southern Journal of Applied Forestry. 8(3): 163-168.

A ridge site in the Appalachian Highlands of North Carolina was prepared for planting white pine seedlings by treatment with herbicide. A pellet formulation of picloram containing 10 percent acid equivalent was applied in May. Control of rhododendron, laurel and other hardwood vegetation was sufficient to allow pine establishment. White pine survival was 96 percent 18 months after planting. Inoculation of seedlings with a

mycorrhizal fungus did not significantly affect seedling survival, total height, seasonal height growth, or basal diameter in the field. Height growth the second growing season after planting 6-month, container-grown stock averaged 5.1 to 7.5 inches. Eighteen months after planting, total seedling height averaged 13.3 inches, with the tallest >29.1 inches. Both height and diameter growth of white pine seedlings were inversely related to shading from remaining vegetation.

444. **Nelson, Thomas C. 1955.** Chestnut replacement in the southern highlands. Ecology. 36: 352-353.

Seventeen 1/5-acre plots were established in 1934 prior to the onset of chestnut blight and were resurveyed in 1941 and 1953. Chestnut decreased from 41 to 1 percent of total basal area from 1934 to 1953. Basal area of yellow-poplar, black oak, and scarlet oak increased while other species remained approximately the same or decreased. Invasion of openings was primarily by sourwood, cucumber magnolia, sweet birch, and eastern hemlock.

445. **Nelson, Thomas C.; Johnson, Edward A. 1954.** Applying unit area control to watershed management. Journal of Forestry. 52: 130.

The authors outline the potential application of unit area control to a watershed for integrated management of timber and water resources.

446. **Neves, Richard J.; Pardue, Garland B. 1983.** Abundance and production of fishes in a small Appalachian stream. Transactions of the American Fisheries Society. 112: 21-26.

Fish production was evaluated at three sites in Guys Run, Virginia, an 8-km, second-order Appalachian stream, from August 1979 through July 1980. Mean standing stock ranged from 21.4 kg/ha upstream to 47.4 kg/ha downstream. Annual production was estimated at 28.4, 31.6, and 39.6 kg/ha/yr in the upper, middle, and lower sections, respectively. Brook trout *Salvelinus fontinalis*, mottled sculpin *Cottus bairdi*, blacknose dace *Rhinichthys atratulus*, and bluehead chub *Nocomis leptocephalus* were the dominant species, accounting for 87 to 99 percent of total fish production in the stream. Annual production/biomass ratios ranged from 0.6 to 1.6 and were consistent with previously determined values for the same or similar species in other small streams.

447. **Nicholson, S. A.; Monk, C. D. 1974.** Plant species diversity in oldfield succession on the Georgia Piedmont. Ecology. 55: 1075-1085.

Species diversity of vascular plants was determined in 51 seral communities ranging from 0.2 to 200 plus years old. Species richness, information content, redundancy, and evenness were calculated for numbers of individuals in four strata (ground layer, shrub, understory, and canopy). Richness in the strata and major growth forms (herbs, woody vines, shrubs, and trees) increased rapidly following their establishment, then at a decreasing rate throughout the remainder of succession. Equitability, on the other hand, increased to near maximum levels immediately after establishment but changed little thereafter. Contrasts in seral richness and equitability trends suggest differing regulatory mechanisms; equitability being regulated primarily by short-term factors and richness by long-term factors.

448. **Nicholson, Stuart A.; Monk, Carl D. 1975.** Changes in several community characteristics associated with forest formation in secondary succession. American Midland Naturalist. 93: 302-310.

Density, biomass, diversity, and niche structure of 51 successionally related plant communities from the Georgia Piedmont were examined. These characteristics displayed large stand-to-stand variation early in succession (0 to 30 years) but little thereafter. The time during succession at which these began to stabilize (about 30 years) coincided with the formation of a closed forest. Relative species importance values approximate a geometric series early in the sere. This reflects low species richness and dominance by a few species in accordance with a niche preemption hypothesis. In later stages, relative species importance value curves flatten, with some suggestion of the log-normal distribution.

449. **Northeastern Forest Experiment Station. 1986.** Atmospheric deposition and eastern forests: cooperative research. NE-INF-72-86. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 18 p.

Atmospheric deposition includes both natural and man-made pollution. This complex phenomenon can be destructive of ecosystems or beneficial. Research programs of the Northeastern and Southeastern Forest Experiment Stations are directed toward measuring and describing atmospheric deposition and its effect on eastern forests. The long-term data banks at Hubbard Brook and Coweeta are featured in this survey of Forest Service research.

450. **Nutter, W. L.; Tkacs, T.; Bush, P. B.; Neary, D. G. 1984.** Simulation of herbicide concentrations in stormflow from forested watersheds. Water Resource Bulletin. 20(6): 851-857.

The breakpoint rainfall hydrology and pesticide options of the field scale model CREAMS were used to predict average concentrations of hexazinone in stormflow from four forested watersheds in the upper Piedmont of Georgia. Predicted concentrations were compared with measured concentrations recorded over a 13-month period. CREAMS accurately predicted hexazinone highest concentrations. The model underestimated the hexazinone concentrations in stormflow after 2 months following pesticide application. In a companion study, the daily rainfall option of the CREAMS model was used to evaluate the relative risk associated with the maximum expected concentration of several herbicides in stormflow from small forested watersheds. The model predicted the following order of potential residue appearance in stormflow: bromacil > triclopyr > hexazinone > picloram > dicamba. Subsurface movement of residues via interflow and deep-leaching losses

are not simulated by the version of CREAMS used in these studies.

451. **Nutter, Wade L. 1973.** The role of soil water in the hydrologic behavior of upland basins. In: Field soil science regime; 1971 August 15-20; New York. Madison, WI: Soil Science Society of America: 181-193.

Except during the most extreme storms, all the precipitation falling on well-vegetated slopes infiltrates and while some reappears in the channel as stormflow, a major portion remains in the basin as dynamic storage. During a storm, the stormflow source area expands out from the stream channel as slopes contribute subsurface flow and the channel system lengthens. After the storm, source areas may continue to expand as subsurface flow feeds the lower slopes near the channel, often leading to a second hydrograph peak. Physical models of hillslope segments have provided some insight into the flow pathways and source areas of subsurface flow.

452. **Nutter, Wade L. 1975.** Moisture and energy conditions in a draining soil mass. Athens, GA: University of Georgia, School of Forest Resources. technical completion report, ERC 0875. 77 p.

A 6.1-m-long, 1.2-m-deep and 0.3-m-wide soil model was packed with a mixed subsurface horizon soil and saturated. Three slopes (25, 15, and 5 degrees) were drained at three depths (120, 80, and 40 cm). Equipotential lines of hydraulic head approach a position normal to the surface during the drainage sequence. The degree of divergence from normal increases with decrease in slope angle. Water content gradients suggest that a zone of active water movement migrates downslope during drainage and may identify the limits of source areas during stormflow. Slope angle exerted the greatest influence on the nature of drainage from a soil mass. Response of a moderately steep and moderately deep slope will be similar to that of a steep and deep slope.

453. **Nutter, Wade L.; Douglass, James E. 1978.** Consequences of harvesting and site preparation in the Piedmont. In: Tippin, T., ed. Proceedings: a symposium on principles of maintaining productivity on prepared sites; 1978 March 21-22; Starkville, MS. New Orleans, LA: U.S. Department of Agriculture; Southern Forest Experiment Station: 65-72.

Piedmont soils suffered years of abuse under agriculture. Now stabilized under forest, these sites are subject to change by harvesting and site preparation. Increased erosion and lowered water quality may occur as a result. These changes can be controlled if the manager specifies conservation practices and the amount of mineral soil that can be exposed during harvest and regeneration. Methods of site preparation applied in the Piedmont need to be reexamined in light of specific silvicultural objectives and disturbance created by various methods.

454. **O'Doherty, Erin Claire. 1985.** Stream-dwelling copepods: their life history and ecological significance. Limnology and Oceanography. 30(3): 554-564.

The stream-dwelling harpacticoid copepod *Bryocamptus zschokkei* was reared in the laboratory at 3.5, 10, 15, 18, and 20 °C with naturally conditioned leaf food source. Egg and naupliar development rates were fastest at 18 °C. A complete life table experiment was conducted at 18 °C. Females were longer-lived than other copepods and produced eggs continuously until death. The intrinsic rate of natural increase (r) and the net reproductive rate (R_0) were found to be lower than those of most copepods. Reproduction is probably continuous throughout the year in the stream, since animals reproduced in the laboratory at the extreme temperatures experienced by the natural population. Since most copepods reproduce seasonally, the annual intrinsic rate of increase of *B. zschokkei* may be comparable to those of other copepods.

455. **O'Hop, Joe; Wallace, J. Bruce. 1983.** Invertebrate drift, discharge and sediment relations in a southern Appalachian headwater stream. Hydrobiologia. 98: 71-84.

Drifting invertebrates and suspended sediments were collected at monthly intervals from June 1977 to May 1978. The numbers and biomass of drifting organisms reflected the seasonal cycles of aquatic insects. Some aquatic organisms showed behavioral drift either during a sample day or during some portion of their life cycle. *Parapsyche cardis* and *Diplectrona modesta* (Trichoptera: Hydropsychidae) dispersed as first instar larvae; few later instars of these two net-spinning caddisflies drifted. The drift of nymphal *Peltoperla maria* (Plecoptera: Peltoperlidae) was related more to detritus transport than to benthic densities or discharge alone. The level of stream invertebrate drift appears related to detritus transport, both between and during storms. Terrestrial invertebrate drift during storms was related to rainfall intensity, canopy washing, and channel expansion.

456. **O'Hop, Joe; Wallace, J. Bruce; Haefner, John D. 1984.** Productions of a stream shredder, *Peltoperla maria* (Plecoptera: Peltoperlidae) in disturbed and undisturbed hardwood catchments. Freshwater Biology. 14: 13-21.

The average benthic density of *Peltoperla maria* in an undisturbed Southern Appalachian stream was more than twice that of a nearby stream draining a previously clear-cut catchment in its 10th year of natural secondary succession. However, *Peltoperla* production estimates, using three methods, do not show a significant difference in production between streams draining the two catchments. We attribute this to quicker growth and slightly higher densities of larger nymphs in the disturbed stream. Thus, conclusions based solely upon numerical densities may lead to erroneus interpretations about the roles organisms play in ecosystems.

457. **O'Neill, R. V.; DeAngelis, D. L.; Waide, J. B.; Allen, T. F. H. 1986.** A hierarchical concept of ecosystems. Monographs in Population Biology 23. Princeton, NJ: Princeton University Press. 254 p.

"Ecosystems" is an intuitively appealing concept to most ecologists, but, in spite of its widespread use, the term remains diffuse and ambiguous. This book argues that previous attempts to define the concept have been based on limited viewpoints. The authors offer a more general line of thought based on hierarchy theory. Their contribution should help to counteract the present separation of subdisciplines in ecology and to bring functional and population/community ecologists closer to a common approach. Developed as a way of understanding highly complex organized systems, hierarchy theory has at its center the idea that organization results from differences in process rates. To the authors, the theory provides an objective way of decomposing ecosystems into their component parts and a promising method for integrating various schools of ecology.

458. **O'Reilly, Patrick J. 1971.** Clock-hour/instantaneous rainfall rate relationships applicable to the Eastern United States. Tech. Note 71-12. Washington, DC: U.S. Air Force Environmental Technical Applications Center. 19 p.

Rainfall drop-size distributions measured by Illinois State Water Survey drop camera at Coweeta Hydrologic Laboratory and two other sites were used to derive climatological estimates of the frequencies of instantaneous rainfall rates at a point and along a surface horizontal path length as a function of the clock-hour rate. These relationships are intended primarily for use over the Eastern United States but may find application for other areas.

459. **Parker, G. R.; Swank, W. T. 1982.** Tree species response to clear cutting a Southern Appalachian watershed. American Midland Naturalist. 108: 304-310.

A 16.1-ha watershed was experimentally clearcut in 1939 and again in 1962. All material over 1 cm in diameter was cut and left in place, thereby minimizing soil disturbance. Density data collected on permanent quadrats, before cutting, 13 years after the first cut and 15 years following the second cut, indicate vegetation response varies by species and physiographic position. There was also a difference in response between the two clearcuts. There was little change in number of tree species found per unit area following the two clearcuts. However, certain species such as *Liriodendron tulipfera* became much more abundant while others decreased in abundance, especially on lower slope to cove and mid-to-upper N and E physiographic positions following the second cut.

460. **Patric, J. H. 1978.** Harvesting effects on soil and water in the eastern hardwood forest. Southern Journal of Applied Forestry. 2(3): 66-73.

For the Eastern United States, there is overwhelming evidence that neither the productivity of forest soil nor the quality of forest water are substantially lessened during or after responsibly managed harvest of wood products. Carelessness, however, damages both resources. The key is forest roads; they cause little adverse effect on soil or water given proper location, drainage, traffic control, and maintenance. The public must better understand that it bears much of the cost for these measures.

461. **Patric, J. H.; Helvey, J. D. 1986.** Some effects of grazing on soil and water in the eastern forest. NE-GTR-115. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 25 p.

This report reviews the effects of woodland grazing upon forest hydrologic processes, erosion and water quality and incorporated results from Coweeta Watershed 7. Authors conclude that detrimental effects of woodland grazing have been overstated.

462. **Patric, James H. 1963.** Forest experiment demonstration area on trail. Appalachian Trailway News. 24(2): 21.

A new experiment in multiple use management at Coweeta is visible to hikers on the Appalachian Trail.

463. **Patric, James H.; Douglass, James E.; Hewlett, John D. 1965.** Soil water absorption by mountain and piedmont forests. Proceedings, Soil Society of America. 29: 303-308.

In the Southern Appalachians and the South Carolina Piedmont, absorption of soil water by tree roots in the top 20 feet of soil was determined from moisture and matric potential measurements under 50- by 50-foot plastic-covered plots. The data indicate that where soil matric potential is kept low by frequent rainfall, most transpired water comes from densely rooted surface soil, whereas soil water well beyond rooting depths returns to the surface during long periods without rain.

464. **Peine, John D. 1989.** The Southern Appalachian Man and Biosphere Cooperative Program. In: Gregg, William P., Jr.; Krugman, Stanley L.; Wood, James D., Jr., eds. Proceedings of the symposium on biosphere reserves, 4th World Wilderness Congress; 1987 September 14-17; Estes Park, CO. Atlanta, GA: U.S. Department of the Interior, National Park Service: 142-152.

The Southern Appalachian region has been chosen for the development of a prototype action program for the Man and the Biosphere (MAB) Program in North America. The existing Biosphere Reserves of the area, Coweeta Hydrologic Laboratory and Great Smoky Mountains National Park, are described, along with Oak Ridge National Environmental Research Park, which has been nominated for biosphere reserve status. The history of MAB Programs in the region is discussed, along with plans for the future, which include the establishment of a coordinating organization consisting of agencies and institutions dedicated to the establishment of collaborative efforts associated with MAB Program.

465. **Penman, H. L. 1956.** Estimating evaporation. Transactions, American Geophysical Union. 37(1): 43-50.

Penman's classic energy balance combination equation for estimating evaporation was applied to climatic data from Wagon Wheel Gap and Coweeta. Computed totals of evaporation were compared to estimates derived from hydrologic data. Discrepancies between energy balance and hydrologic estimates for Coweeta Watershed 17 were assumed to be due to errors in precipitation and/or runoff measurements, causing the author to conclude that the results of the clearcutting experiment should be reexamined. Discussions by Blaney, Wilm, and Penman reflect differences between the biological and purely physical views of the evapotranspiration process.

466. **Perlmutter, Daniel G.; Meyer, Judy L. 1991.** The impact of a stream-dwelling harpacticoid copepod upon detritally associated bacteria. Ecology. 72(6): 2170-2180.

Natural densities of common stream-dwelling *Attheyella* reduced the density and biomass while increasing the production rate of detritally associated bacteria. Bacterial density was reduced by as much as 58 percent and rod-shaped bacteria were reduced as much as 27 percent. *Attheyella* selectively removed larger rod-shaped bacteria, which contributed to the reduction in bacterial biomass. With copepods present, bacterial biomass was reduced as much as 45 percent. Estimated rates of ingestion of bacterial carbon by copepods are comparable to values for marine harpacticoids. Bacterial biomass appears to be a more important food source to microdetritivores than to macrodetritivores in streams.

467. **Peters, G. T.; Webster, J. R.; Benfield, E. F. 1987.** Microbial activity associated with seston in headwater streams: effects of nitrogen, phosphorus and temperature. Freshwater Biology. 18: 405-413.

The influences of temperature and dissolved nitrates and phosphates on microbial activity associated with suspended fine particulate organic matter (seston) were evaluated in four headwater streams. Temperature manipulations of +5 °C always induced significant changes in glucose mineralization and thymidine incorporation. Nutrient amendments induced no significant alterations in bacterial mineralization or incorporation. Micro-organisms attached to refractory particulate organic matter do not appear to be limited by nitrogen or phosphorus. Results indicate that variations in water temperature resulting from diurnal and seasonal temperature fluctuations, forest clear-cutting, and catchment elevation and aspect can have marked effects upon microbial activity and production, while short-term alterations in nutrient regime appear to have no significant effect on microbial activity associated with seston.

468. **Petersen, Ronald H. 1969.** Notes on Cantharelloid fungi - two: some new taxa, and notes on *Pseudocraterellus*. Persoonia. 5(3): 211-223.

A new species of *Craterellus*, *C. carolinensis*, is described. Descriptions are given for the type specimens of *Thelephora subundulata* and *Stereum calyculus* and for representative specimens of *Craterellus sinuosus*, *C. crispus*, and *Cantharellus lutescens* sensu Fr. 1821. Comments on the relative taxonomic relevance of accepting *Pseudocraterellus* at generic rank are made. Two North American varieties of *Cantharellus cibarius* thought to have wide distribution are informally described.

469. **Phillips, Donald L.; Murdy, William H. 1985.** Effects of rhododendron (*Rhododendron maximum* L.) on regeneration of Southern Appalachian hardwoods. Forest Science. 31: 226-233.

The long-term record of forest composition at Coweeta was used to assess the change in tree regeneration patterns over a 34 to 38-year period, and to evaluate the impact of rhododendron on that change. Density-diameter distributions of dominant tree species were determined from 1934 to 1935 and 1969 to 1972 inventories of high-density rhododendron (HR) and low density rhododendron (LR) plots. Oak and maple regeneration, which was abundant in 1934-1935 due to past disturbance, decreased by 1969-1972 as the canopy closed. Total tree regeneration was lower in HR plots than in LR plots and the magnitude of the difference increased with time. From 1969 to 1972, regeneration of chestnut oak and white oak was depressed in HR plots, whereas that of red maple was not; scarlet oak and black oak regeneration was poor at all sites regardless of rhododendron. Hemlock was unique among canopy species in that its sapling density increased with time and abundance of rhododendron.

470. **Phillips, N. A.; Rowe, R.; Todd, R. L. 1977.** The role of nitrification in nutrient cycling of forested ecosystems. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 579-590.

In this review, nitrate-nitrogen levels in streamflow are compared for a number of manipulated forested watersheds. The microbial mediated conversion of ammonium-nitrogen to nitrate-nitrogen (nitrification) is discussed as it relates to nitrate-nitrogen content in runoff water. Finally, hypotheses for system control of the nitrification process are reviewed.

471. **Pittillo, J. Dan; Lee, Martha. 1984.** Reference plant collection of the Coweeta Hydrologic Laboratory. Gen. Tech. Rep. SE-29. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 34 p.

This report describes a botanical survey of Coweeta and lists the 604 taxa in the reference collection.

472. **Potter, C. S. 1991.** Nutrient leaching from *Acer rubrum* leaves by experimental acid rainfall. Canadian Journal of Forest Research. 21: 222-229.

Freshly collected *Acer rubrum* L. leaves from a regenerating forest stand were washed with experimental acid rainfall (pH 4.6). Nutrient leaching rates from undamaged leaves were significant for SO_4, K, Ca, and Mg, whereas NO_3-N was absorbed from rainfall. Significantly greater leaching and absorption occurred in artificially

damaged leaves. Comparisons between leaching transfers and foliar nutrient pools showed that base cation (K, Ca, and Mg) leaching losses account for up to 25 percent of foliar pools, whereas absorption of NO_3-N and NH_4-N from precipitation can increase total foliar N by almost 2 percent. Projected growing-season cation leaching losses from damaged leaves were in agreement with previously reported whole-canopy leaching fluxes based on analysis of throughfall. Nutrient leaching losses from young, rapidly growing tree leaves may be lower than fluxes for more mature forest stands.

473. **Potter, Christopher, S. 1992.** Stemflow nutrient inputs to soil in a successional hardwood forest. Plant and Soil. 140: 249-254.

Stemflow and throughfall from an 8-year-old Southern Appalachian hardwood forest were collected to examine the relative importance of tree bole nutrient leaching in response to acid deposition. Samples were analyzed for four dormant-season and 11 growing-season rainstorm events. Results showed that, relative to throughfall fluxes, stemflow accounted for approximately 8.5 percent of total water reaching the forest floor during both dormant and growing season storms. Relative to foliar leaching, K, SO_4, and PO_4 ions appear to be the most easily leached ions from young tree stems. The proportion of nitrate and base cation from stemflow fluxes increased significantly with growing-season storm-event duration, suggesting that the stem-surface nutrient pool is depleted by precipitation more slowly than the foliar pool. Stemflow fluxes of SO_4 and K were consistently higher than reported for more mature forest stands. Small-scale stemflow inputs of ions to the forest floor may be important in early successional ecosystems.

474. **Potter, Christopher S.; Ragsdale, Harvey L. 1991.** Dry deposition washoff from forest tree leaves by experimental acid rainfall. Atmospheric Environment. 25A (2): 341-349.

Freshly collected leaves from a regenerating forest stand were treated with experimental acid rainfall of pH 4.6 in short-duration laboratory washing trials. The dynamics of initial sulfate and potassium washoff from leaf surfaces were found to be similar between elements and among species. Sulfate and potassium followed negative exponential foliar element washoff curves. Potassium leaching from foliage may occur. The time to complete the initial element washoff was 6 to 8 minutes, similar to previously reported leaf immersion washing times. Potassium was washed from leaf surfaces at a faster rate than was sulfate. Tree species had generally similar dry deposition washoff amounts and rates within trials. Washoff from lower leaf surfaces was negligible. The washoff curve analysis presented in this study appears to produce an accurate estimate of previous dry deposition to leaf surfaces, and eliminates many of the problems and limitations associated with bulk leaf-washing immersion approaches.

475. **Potter, Christopher S.; Ragsdale, Harvey L.; Swank, Wayne T. 1991.** Atmospheric deposition and foliar leaching in a regenerating Southern Appalachian forest canopy. Journal of Ecology. 79: 97-115.

Incident precipitation, throughfall and stemflow were collected to determine net canopy element fluxes, and to quantify canopy exchange and dry deposition rates in a regenerating Southern Appalachian forest. Net throughfall fluxes showed consistent canopy effects on rainfall chemistry, with SO_4, PO_4, Cl, K, Ca and Mg added to rainfall by foliage, whereas NO_3-N, NH_4-N and H ions were absorbed from precipitation. Storm characteristics accounted for the largest portion of the variability in growing season net throughfall fluxes, suggesting that canopy exchange was the major mechanism of throughfall transfer.

476. **Pringle, Catherine M.; Naiman, Robert J.; Bretschko, Gernot; Karr, James R.; Oswood, Mark W.; Webster, Jackson R.; Welcomme, Robin L.; Winterbourn, Michael J. 1988.** Patch dynamics in lotic systems: the stream as a mosaic. Journal of the North American Benthological Society. 7(4): 503-524.

The concepts of landscape ecology and patch dynamics can be applied to lotic systems by investigation of pattern and process in lotic ecosystems over various scales. Patch characteristics include: size, size distribution within the system, juxtaposition, diversity, duration, and mechanisms affecting patch formation. Applications include: (1) response of periphyton communities to nutrient patches; (2) effects of patch dynamics on nutrient spiraling; (3) riparian patch dynamics and effects of leaf litter characteristics on lotic food webs; (4) beaver-induced patch dynamics; and (5) patch dynamics of river floodplains. A patch dynamics perspective coupled with a strong experimental approach can enhance the utility and predictive power of unifying concepts in lotic ecology, such as the river continuum hypothesis and nutrient spiraling, through its focus on organismal and process-specific building blocks of lotic systems.

477. **Progressive Farmer. 1953.** Woods grazing may be bad. Progressive Farmer, Georgia-Alabama-Florida Edition; January: 111.

Cattle gains, vegetative growth, and soil relations on a forested Appalachian watershed after 11 years of cattle grazing are reviewed.

478. **Qualls, Robert G.; Haines, Bruce L. 1990.** The influence of humic substances on the aerobic decomposition of submerged leaf litter. Hydrobiologia. 206: 133-138.

Leaf material was incubated in flasks containing streamwater in which the pH and the concentration of isolated fulvic acid were varied independently of one another. Decomposition of the leaf material was slower at pH 4 than at pH 5 or 7, but the concentration of fulvic acid had no effect when the pH was held constant. At pH 5, 20 mg C L^{-1} humic acid also had no effect on decomposition. High concentrations of dissolved fulvic

acids may contribute to the slow decomposition of plant litter characteristic of many wetlands through their contribution to hydrogen ion activity, but we could find no evidence for other properties of fulvic acid that inhibit leaf litter decomposition.

479. **Qualls, Robert G.; Haines, Bruce L. 1991.** Geochemistry of dissolved organic nutrients in water percolating through a forest ecosystem. Soil Science Society of America Journal. 55: 1112-1123.

Dissolved organic matter (DOM) is a major vehicle for the translocation and loss of N and P from forest ecosystems. The chemical properties of DOM and its interactions with soil surfaces are crucial in determining the mobility of these organic nutrients. DOM was fractionated from throughfall, soil horizons, and stream water from an Appalachian mountain forest ecosystem into hydrophobic or hydrophilic acids, neutrals, and bases. Each fraction was analyzed for dissolved organic C, N, and P.

480. **Qualls, Robert G.; Haines, Bruce L. 1992.** Biodegradability of dissolved organic matter in forest throughfall, soil solution, and stream water. Soil Science Society of America Journal. 56(2): 578-586.

High concentrations of dissolved organic matter (DOM) were leached into rainwater passing through the canopy and forest floor of an oak-hickory forest. More than 95 percent of this dissolved organic C (DOC) and N (DON) was removed as water percolated through the soil profile and left the ecosystem in streamwater. Samples of DOM from throughfall, forest-floor water, soil water from A and B soil horizons, and streamwater were inoculated with soil and stream microbes and incubated in solution for 134 days. In general, only 14 to 33 percent of the DOC in forest floor, soil solution, and stream samples decomposed during the incubation. Biodegradability of DOM in the ecosystem profile declined vertically from throughfall to the A horizon and then increased with depth. The DON generally did not decay faster than the DOC. Throughfall DOM could be decomposed during its passage through the upper soil, but decomposition seems too slow to be responsible for the bulk of removal of DON and DOC that occurs in the mineral soil. Adsorption is more likely responsible for maintaining low DOC substrate concentrations in the mineral soil and preventing its loss into stream water.

481. **Qualls, Robert; Haines, Bruce L. 1992.** Measuring adsorption isotherms using continuous, unsaturated flow through intact soil cores. Soil Science Society of America Journal. 56: 456-460.

Conventional batch adsorption-isotherm experiments are conducted under conditions that are generally not representative of field conditions. Our objective was to develop and illustrate a technique to obtain adsorption-isotherm data under more realistic conditions. Soil cores were placed on filter funnels and continuous flow was induced by controlled vacuum. Solution, 10 times the weight of the soil, was applied and recycled until apparent equilibrium concentrations were observed. The amount of solution in contact with soil at any instant was small. The procedure was replicated on separate cores with different initial solute concentrations. The technique was compared with conventional batch-adsorption data. Isotherms using both methods were linear but the slope of the batch isotherm was somewhat less.

482. **Qualls, Robert G.; Haines, Bruce L.; Swank, Wayne T. 1991.** Fluxes of dissolved organic nutrients and humic substances in a deciduous forest. Ecology. 72(1): 254-266.

This paper evaluates the importance of dissolved organic matter as a vehicle for the movement of N and P from the canopy and the forest floor into the mineral soil of a deciduous forest. The origin and nature of dissolved organic matter from the forest floor was also examined. The average annual output from the forest floor in the form of dissolved organic matter was 18, 28, and 14 percent of the input in solid litterfall for C, N, and P, respectively. In throughfall, about half of the dissolved N and P was organic. But, in solution percolating from the forest floor, 94 percent of the N and 64 percent of the P was organic. Leaching from the forest floor was not a source of inorganic N and P for the mineral soil. Instead, the forest floor was a sink for the removal of these inorganic nutrients delivered in throughfall. Microbial immobilization was the most likely explanation for much of the inorganic nutrient removal. In contrast, the forest floor was an abundant contributor of N and P to the mineral soil in the form of dissolved, and possibly particulate, organic matter. Most of the flux of nitrogen from the forest floor to the A horizon was carried by humic substances and highly colored hydrophilic acids.

483. **Ragsdale, J. L.; Berish, C. W. 1988.** Trace metals in the atmosphere, forest floor, soil, and vegetation. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 367-380.

Substantial increases in ambient levels of toxic trace metals, such as lead (Pb), are directly attributable to coal combustion, metal smelting, waste disposal, and the 20th century use of leaded alkyl derivatives in gasoline. The soil column (O1 + O2, A, and upper B horizon) of two, low-elevation control watersheds in the Coweeta Basin contains lower concentrations of trace elements (Cu, Zn, Pb, and Cd) than commonly reported for many other North American sites. The litter-humus forest floor burdens of Cu, Pb, and Zn were 20 times smaller than found in forests of the industrialized Northeastern United States. Lead concentrations in the high-elevation Albert Mountain litter and humus samples were significantly greater than those at the lower elevations. The greater lead concentrations at high elevation result from long-range transport and deposition of airborne lead particles.

484. **Reeves, M.; Duguid, J. O. 1975.** Water movement through saturated-unsaturated porous media: a finite-element Galerkin model. Oak Ridge National

Laboratory-4927. Oak Ridge, TN: Oak Ridge National Laboratory. 236 p.

A two-dimensional transient model for flow through saturated-unsaturated porous media is given with complete Fortran code. This model numerically solves the partial differential equations that are highly nonlinear. The Galerkin finite-element method is superior to the finite-difference method used by previous investigators. Infiltration into or seepage from the surface may be simulated. Different material properties may be assigned to allow simulation of layered geologic formations. The computer model gives good results in a simulation of experimental data obtained from an inclined soil slab at Coweeta Hydrologic Laboratory. Here a comparison with finite-difference model developed by R. A. Freeze is made. By exploiting the flexibility of the finite-element geometrical discretization, the user may easily reduce computer running time by a factor of two.

485. **Riekerk, H.; Neary, D. G.; Swank, W. T. 1989.** The magnitude of upland silvicultural nonpoint source pollution in the South. In: Hook, Donal D.; Lea, Russ, eds. Proceedings of the symposium: the forested wetlands of the Southern United States; 1988 July 12-14; Orlando, FL. Gen. Tech. Rep. SE-50. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 8-18.

Streamflow water quality data from intensive silvicultural practices in the Southern United States are summarized and discussed with respect to regional differences of nonpoint source pollution and best management practices. Suspended sediment production by silviculture was low in the mountains and lower coastal plain, but high in the Piedmont and upper coastal plain regions. This reflected an interaction between site preparation intensity and topographic relief. Cation nutrient export after harvesting in the mountains was increased by higher nitrate carrier-ion production and by more runoff. Nutrient exports in the Piedmont and upper coastal plain regions were controlled by the degree of soil disturbance and by the recovery rate of vegetation. Nutrient exports in the lower coastal plain were not much affected by intensive silviculture. Information gaps and research needs for upland nonpoint source pollution effects on wetlands are identified.

486. **Risley, Lance S. 1984.** A modified rope-climbing technique for reaching canopies of forest trees in remote areas. Journal of Georgia Entomological Society. 19: 533-538.

A method is described for gaining access to canopies of mature deciduous trees in remote areas. This rope-climbing technique, modified from those used in caving, provides a light-weight, portable, nondestructive alternative to pole climbers, and an inexpensive alternative to scaffolding, ladders, towers, and hydraulic lifts. The method has been successfully applied in an investigation of canopy arthropods for 3 years in the Nantahala Mountains, North Carolina. Attention is given to equipment, cost, necessary skills, and safety.

487. **Risley, Lance S. 1986.** The influence of herbivores on seasonal leaf-fall: premature leaf abscission and petiole clipping. Journal of Agricultural Entomology. 3(2): 152-162.

A review of the literature on insect-plant interactions documents mechanisms by which herbivores regulate the transfer of materials from host plants to litter and soil decomposer communities. Emphasis is placed on the acceleration of seasonal leaf fall through premature abscission of insect-damaged leaves and petiole clipping by caterpillars. Green leaves falling during the growing season are evidence for the occurrence of both phenomena. Greenfall was 1.3 percent of total foliar production for dominant tree species on a site at Coweeta. Significantly higher percent leaf area removed in greenfall compared with in situ leaves is further evidence that herbivores accelerated leaf fall. The addition of greenfall to insect fecal pellet production strengthens the role of herbivores as regulators of nutrient cycling in forest ecosystems.

488. **Risley, Lance S. 1993.** Effect of simulated insect herbivore damage on survival of tree leaves. Environmental Entomology. 22(1): 57-61.

Herbivores cause leaf abscission. The amount of damage required to initiate abscission was investigated in a Southern Appalachian forest by mechanically damaging leaves from red maple, flowering dogwood, tuliptree, and chestnut oak, and monitoring leaf survival. Leaf survival was negatively related to percentage of leaf area removed. Timing of leaf abscission was not significantly different among tree species in 1985. In 1986, with a severe drought, there were significant differences among species. Insect damage after treatment was measured in 1986 and differed significantly among treatment levels in tuliptree only. Abscission of damaged leaves usually occurred at the beginning of normal autumn senescence. These results are interpreted with respect to insect-mediated litterfall and its potential influence on forest floor decomposer organisms.

489. **Risley, Lance S.; Crossley, D. A., Jr. 1988.** Herbivore-caused greenfall in the Southern Appalachians. Ecology. 69(4): 1118-1127.

Freshly fallen green leaves (greenfall) were collected from plots on four forested watersheds differing in aspect and treatment history at Coweeta. Herbivore-caused greenfall biomass was significantly greater than unexplained greenfall. Herbivore-caused greenfall was due to petiole-clipping caterpillars, petiole borers, mining by microlepidoptera, or discarded leaf fragments. Leaves from 25 species of deciduous trees and woody vines in foliar litterfall were collected from litter traps. Despite differences in aspect and stand age (10 years, 23 years, mature), patterns of greenfall were similar among watersheds. Seasonal inputs of greenfall to the forest floor were <5 percent of total foliar production but were greater than combined inputs of insect fecal pellets and body parts. Greenfall occurred continuously during the growing season and is a widespread phenomenon that may be an important resource for decomposers.

490. **Risley, Lance S.; Crossley, D. A., Jr. 1993.** Contribution of herbivore-caused greenfall to litterfall nitrogen flux in several Southern Appalachian forested watersheds. American Midland Naturalist. 129: 67-74.

Herbivorous insects are responsible for a portion of foliar litterfall in forest ecosystems. There is little information on the nutrient content of this litterfall despite speculation that herbivores regulate nutrient cycles. Herbivore-caused "greenfall" (green leaves falling as a direct result of herbivore feeding activity) was quantified for four Appalachian watersheds and samples analyzed for total nitrogen. Concentrations of nitrogen in greenfall fluctuated significantly from May through September and were always higher than concentrations of nitrogen in autumn-senesced leaves. Annual inputs of greenfall nitrogen ranged from 0.08-0.18 g/m^2/year and resulted in 3.2 to 6.5 percent of total nitrogen transferred to the forest floor in autumn foliar litterfall. Greenfall is viewed as a high-quality substrate supplying nitrogen to decomposer organisms and is thus a potential mechanism by which herbivorous insects speed nutrient cycling.

491. **Roberson, Sheila. 1989.** Death on the hill. The University of Georgia Research Reporter. 19(3): 11-14.

A popularized report of the cooperative Long Term Ecological Research program at Coweeta with the University of Georgia.

492. **Robinson, Vernon L.; Fisher, Edward L. 1982.** High-lead yarding costs in the Southern Appalachians. Southern Journal of Applied Forestry. 6: 172-176.

An analysis was made of the time devoted to the various work-and-delay elements of high-lead cable logging. A comparison of the resulting per unit volume with those of a conventional logging system shows that in spite of inefficiencies, the cable system is competitive, with a difference of only $2.85 per Mbm (Doyle rule) between the two systems. With better preplanning of sets, better crew organization and more experience with the equipment, the cable yarding costs should decline, making it a viable alternative to conventional logging in the Southern Appalachians.

493. **Robinson, Vernon L.; Fisher, Edward L. 1983.** A model of turn-time requirements in a highlead yarding system. Forest Science. 29(3): 641-652.

A theoretical model is developed for specifying regression equations for the time requirements of four yarding elements in the highlead yarding system. The equations are estimated from sample data taken from a commercial logging operation in the Southern Appalachians. The hook and unhook equations proved to be the most difficult to specify and estimate. The outhaul and inhaul times were a function of the operating gear, the slope distance to the log, and the work done on the cable and log.

494. **Ross, Douglas H.; Wallace, J. Bruce. 1981.** Production of *Brachycentrus spinae* Ross (Trichoptera: Brachycentridae) and its role in seston dynamics of a Southern Appalachian stream. Environmental Entomology. 10: 240-248.

Annual production and turnover ratios for *Brachycentrus spinae* (Trichoptera) were estimated and production attributable to five food types was calculated. Annual food accounted for 62 percent of the *B. spinae* production. While larvae ingested only 0.00007 percent m^{-2} of total available summer seston, they selectively captured animal material, consuming 3.5 times the amount entering the study section. These data suggested that the animal component of the seston must be replaced every 400 m to support *Brachycentrus* feeding alone. While this species exerted a minor influence on seston quantity, its selective capture of high-quality animal food could significantly alter seston quality.

495. **Ross, Douglas H.; Wallace, J. Bruce. 1982.** Factors influencing the longitudinal distribution of larval Hydropsychidae (Trichoptera) in a Southern Appalachian stream system. Hydrobiologia. 96: 185-199.

The influence of physical habitat variables and suspended particulate organic matter (seston) on the distribution and production of eight species of larval Hydropsychidae was studied along a 6.4-km section of a Southern Appalachian stream. Samples were collected at six stations encompassing stream orders 1 to 4 and an elevation range of 610 m. Multivariate analysis of covariance (using time as the covariable) and discriminant function analysis were used to examine habitat differences due to the following variables: current velocity; coarse benthic detritus; substrate composition (by particle size); substrate heterogeneity; degree-days; and diel temperature fluctuation. Hydropsychid species distribution along the stream system followed subfamily lines, i.e., Arctopsychinae and Diplectroninae were more abundant and productive in the upper 4.5 km of the stream, while Hydropsychinae were dominant in the lower 1.9 km. Diel temperature fluctuation was the habitat variable most highly correlated with patterns of hydropsychid abundance and production.

496. **Ross, Douglas H.; Wallace, J. Bruce. 1983.** Longitudinal patterns of production, food consumption, and seston utilization by net-spinning caddisflies (Trichoptera) in a Southern Appalachian stream. Holarctic Ecology. 6: 270-284.

Larval production of 10 species of *Hydropsychidae* and *Philipotamidae* was studied at six stations along a 6.4 km section of a southern Appalachian stream, encompassing stream orders 1 through 4 and a 600-m elevation change. Species-specific production estimates ranged from 23 to 983 mg AFDM/m^2/year. These low values are attributed to the paucity of nutrients in these undisturbed headwater streams that reduces detrital food quality, algal growth, and production of smaller invertebrates eaten by hydropsychids. Animal food supported the majority of hydropsychid production (72 percent); philopotamids relied primarily on fine detritus (80 percent) and diatoms (15 percent). Net-spinning caddisflies had a minor impact on seston quantity, consuming only 0.0003 to 0.005 percent

of the total seston (including invertebrate drift) passing over a m^2 of substrate annually.

497. **Rowe, R.; Todd, R. L.; Waide, J. B. 1977.** A microtechnique for MPN analysis. Applied Environmental Microbiology. 33: 675-680.

A microtechnique based on the most-probable-number (MPN) method has been developed for the enumeration of the ammonium-oxidizing population in soil samples. An MPN table for a research design (i.e., 12 dilutions, 8 replicates per dilution) is presented. A correlation of 0.68 was found between MPN's determined by the microtechnique and the standard tube technique. Higher MPN's were obtained with the microtechnique with increased accuracy in endpoint determinations being a possible cause. Considerable savings of time, space, equipment, and reagents are observed using this method. The microtechnique described may be adapted to other microbial populations using various types of media and endpoint determinations.

498. **Santee, William R.; Monk, Carl D. 1981.** Stem diameter and dry weight relationships in *Tsuga canadensis* (L.) Carr. Bulletin of the Torrey Botanical Club. 108: 320-323.

Stem diameters and dry weight for bole, branches, bark and needles are given for 20 hemlock trees from the Southern Appalachians. Simple allometric equations relating dry weight to d.b.h. are also presented. Nutrient concentrations for 15 elements are included.

499. **Schmid, Marvin. 1974.** Managing a watershed. The Conservationist. 29(2): 25.

Changes in attitudes toward forest management on municipal watersheds are discussed.

500. **Scholl, David G.; Hibbert, Alden R. 1973.** Unsaturated flow properties used to predict outflow and evaporation from a sloping lysimeter. Water Resources Research. 9(6): 1645-1655.

Soil moisture content and pressure potential measurements were used to determine the moisture flux, hydraulic gradients, and dynamic conductivity of a 200-foot sloping soil lysimeter. A vertical unsaturated Darcian analysis was used to evaluate conductivity when evapotranspiration was eliminated by sealing the model surface with plastic. The moisture flux term in the Darcy equation was determined by evaluating moisture content change in depth and time and agreed with measured outflow. Conductivities were solved from flux and hydraulic gradients, and corresponding water contents were assigned. Evapotranspiration was solved after grass was established by using a water balance based on moisture content and potential, rainfall, and conductivity. Results at the deepest level in the profile agreed well with those based on actual outflow.

501. **Schowalter, T. D. 1992.** Heterogeneity of decomposition and nutrient dynamics of oak (*Quercus*) logs during the first 2 years of decomposition. Canadian Journal of Forest Research. 22: 161-166.

Decomposition of oak logs was compared in Oregon, Minnesota, Kansas, and North Carolina during the first 2 years on the ground. Decomposition reflected qualitative differences among log substrates. Inner bark had the highest nutritional quality and was the focus of insect and microbial activity during this early stage of decomposition; only 20 percent of initial mass remained after 2 years. Sapwood decayed more slowly than heartwood. Heartwood lost 50 percent of its mass during the first year, but showed no further loss during the second year. Nutrient content generally declined during decomposition, but P accumulated in heartwood and Na accumulated in sapwood and heartwood during the second year. Results indicate that decomposition of whole logs integrates different decomposition rates and lag time. Multiple-exponential models may be necessary to predict rates and sources of carbon and nutrient release to the atmosphere and soil.

502. **Schowalter, T. D.; Crossley, D. A., Jr. 1983.** Forest canopy arthropods as sodium, potassium, magnesium and calcium pools in forests. Forest Ecology and Management. 7: 143-148.

Concentrations were measured of sodium, potassium, magnesium, and calcium in forest canopy arthropod functional groups collected from vegetation of clearcut and uncut hardwood forests during 1977 and 1978. Functional groups differed significantly in concentrations of the four elements. Spiders had the significantly highest sodium concentrations, followed in decreasing order by some other predators and then herbivores. Caterpillars and sawfly larvae had the significantly highest potassium and magnesium concentrations and high calcium concentrations. Our data indicate that nutrients contained in nominal biomass of canopy arthropods do not contribute significantly to litter nutrient pools.

503. **Schowalter, T. D.; Crossley, D. A., Jr. 1988.** Canopy arthropods and their response to forest disturbance. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 207-218.

Most ecological studies of forest canopy arthropods have focused on population dynamics. However, few studies have documented changes in arthropod assemblages resulting from changes in environmental conditions. Forest canopy arthropods have been particularly difficult to study because of taxonomic complexity and inaccessability of high canopies. We have compiled data from four watershed-level studies representing 8 watershed-years. Included are four studies of canopy arthropods in mature canopies, one study of arthropods in first- and second-year regrowth, and one study of arthropods in 13-year regrowth. Studies of canopy arthropod assemblages at Coweeta support a hypothesis that host resource allocation pattern and consumer response constitute the mechanism for cybernetic control of net primary production in temporally-variable environments.

504. **Schowalter, T. D.; Hargrove, W. W.; Crossley, D. A., Jr. 1986.** Herbivory in forested ecosystems. Annual Review of Entomology. 31: 177-196.

Forest canopies support a complex assemblage of herbivores that are inconspicuous except when population outbreaks produce noticeable defoliation. Foliage consumption during nonoutbreak periods has been measured as 5 to 15 percent of leaf area production in temperate forests, but the techniques used may underestimate actual herbivory. Foliage loss may reach 100 percent of foliage production during herbivore population outbreaks. Herbivory might act as a homeostatic mechanism at the ecosystem level, regulating primary production and may be the driving force behind ecosystem succession and nutrient cycling processes. This review considers the activities of foliage-consuming and sap-feeding insects. The purpose is to integrate the biochemical and ecosystem views of herbivory, emphasizing factors that influence herbivory in forest ecosystems and the consequences of herbivory at the tree and ecosystem levels of resolution.

505. **Schowalter, T. D.; Webb, J. Warren; Crossley, D. A., Jr. 1981.** Community structure and nutrient content of canopy arthropods in clearcut and uncut forest ecosystems. Ecology. 62: 1010-1019.

Differences in canopy arthropod community structure, major cation content, and calculated nutrient consumption between clearcut and undisturbed hardwood forest watersheds at Coweeta were observed during the first two growing seasons following cutting. Canopy arthropod biomass was about 0.08 percent of foliage biomass on both watersheds. Aphid mass increased 23 times and ant mass increased 6 times per unit following cutting. These had lower nutrient concentrations than did chewing herbivores and predators. Arthropod K concentrations were 33 percent lower on the clearcut; Na, K, and Mg concentrations were 20 to 50 percent higher in 1978 than in 1977. Arthropod Mg and Ca concentrations were reduced significantly by the effect of drought. Consumption estimates indicated increased nutrient translocation from foliage via arthropods following cutting. Canopy arthropod responses to changes in nutrient availability following disturbance could have increased nutrient cycling rates and contributed to nutrient retention by the recovering ecosystem.

506. **Schowalter, Timothy D. 1981.** Insect herbivore relationship to the state of the host plant: biotic regulation of ecosystem nutrient cycling through ecological succession. Oikos. 37: 126-130.

This paper provides a conceptual framework for increasing understanding of the relationships between plant resistance to insect herbivores and insect herbivore influences on ecosystem nutrient cycling and succession. For a given plant species, adequate nutrient/light availability favors establishment and productivity; small insect herbivore populations regulated by plant biochemistry stimulate primary productivity and short-term nutrient cycling. As biomass and competition for nutrients and light increase during succession, plants become stressed as they approach their tolerance limits. Earlier successional plant species initially dominating the plant community have higher nutrient/light requirements and become stressed sooner than later successional plant species. Abundance and stress make the earlier plant species more apparent and susceptible than later plant species to insect herbivores.

507. **Schreuder, H. T.; Swank, W. T. 1971.** A comparison of several statistical models in forest biomass and surface area estimation. In: Forest biomass studies, 15th meeting of the International Union of Forest Research Organizations; 1971 March 15-20; Gainesville, FL. Misc. Publ. 132. Orono, ME: University of Maine, Life Sciences and Agriculture Experiment Station: 123-136.

The squared correlation and log likelihood techniques are discussed and used to evaluate statistical estimation models for eastern white pine biomass and surface area data. Three a priori linear models are considered: (1) an unweighted untransformed model, (2) a weighted untransformed model, and (3) a log-log transformation model.

508. **Schreuder, H. T.; Swank, W. T. 1973.** Statistical considerations in sampling biomass and surface area over time for a *Pinus strobus* L. forest. In: IUFRO biomass studies, working party on the mensuration of the forest biomass, S4.01 mensuration growth and yield; 1973 June 25-29; Nancy, France; 1973 August 20-24; Vancouver, BC. Orono, ME: University of Maine, College of Life Sciences and Agriculture: 133-141.

A 16.1-ha white pine plantation was sampled at ages 10, 12, and 15 years for biomass and surface area of aboveground tree components. A weighted regression technique is recommended for estimating leaf, branch and stem biomass, and surface area with tree basal area as the independent variable. The double log and double square root models are alternate estimation models deserving serious consideration. For any of these models, data from different years can some times be combined to reduce the number of trees that need to be felled.

509. **Schreuder, Hans T.; Swank, Wayne T. 1974.** Coniferous stands characterized with the Weibull distribution. Canadian Journal of Forestry Research. 4: 518-523.

The Weibull distribution summarized diameter, basal area, surface area, biomass, and crown profile distribution data well for several different ages of white and loblolly pine plantations. The data for diameter, basal area, surface area, and biomass were easily summarized by this one distribution in a theoretically consistent fashion. This is not possible with the normal and the gamma distributions, and the log-normal gives less satisfactory results. The distribution function should prove useful in modeling tree stands since only the parameter values need to be changed over time for the above variables. The change in these parameters may be a good way to characterize and interpret changes in stands over time.

510. **Seastedt, T. R. 1984.** The role of microarthropods in decomposition and mineralization processes. Annual Review of Entomology. 29: 25-46.

Most plant energy and nutrients eventually become incorporated in dead organic matter or detritus. The decomposition of this material and the mineralization of bound inorganic elements are critical to the continued productivity of terrestrial ecosystems. Thus, terrestrial decomposition and mineralization processes have been the subject of considerable scientific effort, and a massive literature on this subject is available. Soil fauna appear to regulate decomposition processes, even though the amount of soil metabolism attributable to soil animals is 10 percent or less of the total. Fungi and bacteria are directly responsible for most decomposition, but a diverse assemblage of protozoans, nematodes, annelids, and arthropods influence the functioning of decomposer flora through feeding activities. This review examines the importance of one component of the soil fauna, the microarthropods, in decomposition and mineralization processes.

511. **Seastedt, T. R.; Crossley, D. A., Jr. 1978.** Further investigations of microarthropod populations using the Merchant-Crossley high-gradient extractor. Journal of the Georgia Entomological Society. 13: 338-344.

Estimates of microarthropod populations from litter and soil at Coweeta vary considerably, depending upon extraction method and technique. Estimates from high-gradient extractions are superior to estimates from both Tullgren funnel extraction and counts from examination of gelatin-embedded litter and soil samples. The high-gradient extractor designed by Merchant and Crossley is inefficient under conditions of high humidity. Microarthropods adhere to condensation on funnel walls. Funnels must be rinsed prior to removing sample vials. In spite of this problem, the design is superior to a similar apparatus employing canister collectors.

512. **Seastedt, T. R.; Crossley, D. A., Jr. 1980.** Effects of microarthropods on the seasonal dynamics of forest litter. Soil Biology and Biochemistry. 12: 337-342.

The amounts of Ca, K, Mg and P were measured in leaf litter contained in litter bags in a Southeastern United States deciduous forest. Half of the litter was treated with naphthalene, a chemical that reduced microarthropod densities to about 10 percent of those found in untreated litter. Phosphorus losses were significantly greater in untreated litter. After initial elemental losses, amounts of Ca, K, and Mg generally increased in 9- to 12-month-old untreated litter, while naphthalene-treated litter generally showed no seasonal dynamics. Seasonal amounts of nutrients in forest litter depend upon elemental mobility, inputs of nutrients in rainfall, throughfall and particulates, and nutrient retention by forest floor biota. Microarthropods increase nutrient loss from forest litter by comminution; however, microbial stimulation as a result of microarthropod feeding activities appears to increase the nutrient retention capacities of forest litter.

513. **Seastedt, T. R.; Crossley, D. A., Jr. 1981.** Microarthropod response following cable logging and clear-cutting in the Southern Appalachians. Ecology. 62: 126-135.

Litter and soil microarthropod populations were monitored following cable logging and clearcutting of a forested watershed (WS 7) at Coweeta. Annual mean densities of microarthropods in litter bags were reduced over 50 percent on the clearcut watershed when compared with an adjacent forested watershed (WS 2), and averaged 8.4 individuals/g of litter on WS 7 vs. 20.4/g on WS 2 ($P < 0.01$). Density estimates obtained from 5-cm-deep sections of litter and soil indicated a 25 percent reduction in densities on WS 7, with a 17-month average of 98900 microarthropods/m^2 on WS 7 vs. 133500 microarthropods/m^2 on WS 2 ($P < 0.001$). In contrast, densities of microarthropods increased over 100 percent in deeper soil horizons (5 to 55 cm), averaging 89800 microarthropods/m^2 on WS 7 vs. 43700 microarthropods/m^2 on WS 2 ($P < 0.001$).

514. **Seastedt, T. R.; Crossley, D. A., Jr. 1981.** Sodium dynamics in forest ecosystems and the animal starvation hypothesis. American Naturalist. 117: 1029-1034.

Sodium may be a critical limiting element for certain vertebrate herbivore populations. It has been hypothesized that the relative exclusion of sodium from the tissues of most land plants may help them against grazing by making it difficult for the grazers to obtain as much of this ion as they need. Contrary to this "animal starvation hypothesis," authors contend that forest trees do not exhibit any aboveground allocation strategy for this element and that sodium concentrations in forest trees are at least one to two orders of magnitude above those levels found in soil percolates. As a null hypothesis, sodium levels in plants do not affect levels of herbivory; however, alternatives include not only the animal starvation hypothesis but also its antithesis, i.e., sodium levels observed in plants stimulate consumption.

515. **Seastedt, T. R.; Crossley, D. A., Jr. 1983.** The influence of arthropods on ecosystems. BioScience. 34(3): 157-161.

Arthropod interactions with plants and microbes influence the amounts of living and dead organic matter and transfers of nutrients in terrestrial ecosystems. Arthropods in the canopy have their greatest effect on mobile elements such as potassium, whereas soil detritivores influence mineralization rates of less mobile elements such as nitrogen, phosphorus, and calcium. Nominal (baseline) herbivory and detritivory combine to speed nutrient cycling and reduce standing crops of decaying plant materials.

516. **Seastedt, T. R.; Crossley, D. A., Jr. 1983.** Nutrients in forest litter treated with naphthalene and simulated throughfall: a field microcosm study. Soil Biology and Biochemistry. 15: 159-165.

The effects of naphthalene (arthropod exclusion) and simulated throughfall (N, P, K, Ca and Mg) additions on the decomposition and mineralization of dogwood (*Cornus*

florida L.) litter were studied by using a field microcosm approach in a Southeastern United States deciduous forest. Treatments without microarthropods decayed more slowly than litter with microarthropods. Simulated throughfall additions alone had no effect on litter decay rates. Fauna, simulated throughfall, and fauna plus simulated throughfall treatments increased the nutrient concentrations of decomposing litter; the treatment with both microarthropods and simulated throughfall generally exhibited the highest nutrient concentrations. Simulated throughfall also significantly increased microarthropod densities in litter. Litter immobilization of elements in throughfall was insignificant in litter with microarthropods; naphthalene-treated litter immobilized up to 8 percent of the elements contained in simulated throughfall.

517. **Seastedt, T. R.; Crossley, D. A., Jr. 1988.** Soil arthropods and their role in decomposition and mineralization processes. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 233-243.

This chapter summarizes the findings of Coweeta research on soil arthropod abundance and response to substrate quantity, substrate quality, and perturbations. About 95 percent of the annual net primary production of mature forests is directly transferred to the detrital food web as foliar litter and woody debris. The decomposition of these substrates and the release of elements contained are necessary for continued productivity of the forests. Most of the chemical energy released during decomposition is processed by bacteria and fungi; however, interactions with a host of invertebrates (primarily protozoans, nematodes, annelids, and arthropods) are responsible for the patterns of nutrient immobilization and mineralization observed in litter and soil. This demonstrates the interdependence between the biotic and abiotic components of the forest floor, and shows that arthropods are both regulated by and regulators of forest floor nutrients and organic matter.

518. **Seastedt, T. R.; Crossley, D. A., Jr.; Hargrove, W. W. 1983.** The effects of low-level consumption by canopy arthropods on the growth and nutrient dynamics of black locust and red maple trees in the Southern Appalachians. Ecology. 64(5): 1040-1048.

The effects of low-level consumption by canopy arthropods on foliage nutrient content, canopy leachates (throughfall), and biomass of 4-year-old black locust (*Robinia pseudoacacia*) and red maple (*Acer rubrum*) were studied in the Southern Appalachians of North Carolina. A carbaryl insecticide was used to reduce foliage consumption from 10 to 2 percent in black locust and from 4 to 1 percent in red maple. Total biomass production (net primary production per kilogram of preseason biomass) was unaffected by the low levels of herbivory observed here. Such nominal herbivory did not stimulate biomass and nutrient accretion by these tree species but did increase the cycling of K and perhaps other elements within these systems.

519. **Seastedt, T. R.; Crossley, D. A., Jr.; Meentemeyer, V.; Waide, J. B. 1983.** A two-year study of leaf litter decomposition as related to macroclimatic factors and microarthropod abundance in the southern Appalachians. Holarctic Ecology. 6: 11-16.

Chestnut oak litter in the Southern Appalachian Mountains decomposes slowly during winter and more rapidly in other seasons. This pattern differed from other studies of litter decomposition in more northern environments where decomposition rates were relatively constant throughout the year or more rapid beneath a winter snow cover. The pattern observed can be approximated by using monthly actual evapotranspiration estimates as a correction factor for the decomposition constant, k, in the commonly used negative exponential decomposition model. Mean microarthropod densities increased from a seasonally weighted estimate of 18.2 ind/g litter during the first year of decomposition to 73.6 ind/g litter during the second year. In spite of this increase, no difference in the rate of weight loss of the litter was observed between the first and second year of the study.

520. **Seastedt, T. R.; Kothari, A.; Crossley, D. A., Jr. 1980.** A simplified gelatine embedding technique for sectioning litter and soil samples. Pedobiologia. 20: 55-59.

The importance of determining structural and functional relationships of soil biota within a systematic framework has been recognized by a number of researchers. Inspection of in situ microflora and fauna is a useful preliminary step in evaluating the roles of various groups within the soil milieu. In this report methods for both embedding and sectioning soils have been simplified. All equipment used is present or readily available to most laboratories. The sectioning device presented is suitable for sectioning gravelly soils. Soil sections prepared by these procedures are useful in both visual confirmation of quantitative analyses of soil flora and fauna as well as in formulating new hypotheses for biota-substrate interactions.

521. **Seastedt, T. R.; Tate, C. M. 1981.** Decomposition rates and nutrient contents of arthropod remains in forest litter. Ecology. 62: 13-19.

Decomposition rates and amounts of calcium, magnesium, potassium, and phosphorus were measured for dead millipedes and crickets buried in forest litter in North Carolina and Georgia. An average of 30 percent of the original mass of millipedes and 14 percent of the original mass of crickets was recovered after 1 year in the litter. Elemental losses generally followed the pattern K > P > Mg > Ca; however, elemental amounts occasionally stabilized and in one experiment calcium increased in amount over time. Decomposition of arthropod carcasses was described by a two-component, negative exponential decay model. Decay coefficients were used with literature estimates of arthropod standing crops to estimate standing crops of mass and elements of arthropod remains in forest litter and soil. Estimates of standing crops of mass, calcium, and magnesium of arthropod remains were greater than those of living forest floor arthropods.

522. **Sihanonth, P.; Todd, R. L. 1977.** Transfer of nutrients from ectomycorrhizal fungi to plant roots. In: Lohm, U.; Persson, T., eds. Soil organisms as components of ecosystems: Proceedings of the 6th international soil zoology colloquium; 1976 June 21-25; Uppsala, Sweden. Ecol. Bull. 25. Uppsala, Sweden: Swedish Soil Science Society: 392-397.

The magnesium, phosphorus, sulfur, potassium and calcium composition of ectomycorrhizae formed by *Pisolithus tinctorius* and *Cenococcum graniforme* was compared with the elemental distribution within the cortex root cells of *Pinus taeda*. The values were obtained by a combination scanning electron microscopy-electron microbeam technique. Significant concentrations of the five elements were observed within the fungus mantle sheath and Hartig net of both ectomycorrhizal types. Elemental concentrations were higher in the ectomycorrhizal root cells than the nonmycorrhizal root cells. This accumulation and transport of nutrients by ectomycorrhizal fungi to root cells is proposed as the major factor in the stimulation of plant growth under low fertility conditions.

523. **Sims, A. L.; Mueller, G. E.; Stout, G. E.; Ackerman, William C. 1964.** Investigation of quantitative determination of point and areal precipitation by radar echo measurements. Urbana, IL: Illinois State Water Survey; final report. 202 p.

A raindrop camera was operated at Mooney Gap, Coweeta Hydrologic Laboratory, for 18 months in cooperation with the Illinois Water Survey and the U.S. Army Electronics Research and Development Laboratory. Graphical presentations of raindrop size and number per cubic meter for this and four other study sites show drop size and count are consistent between storm events and directly related to rainfall rate.

524. **Singer, F. J.; Swank, W. T.; Clebsch, E. E. C. 1982.** Some ecosystem responses to European wild boar rooting in a deciduous forest. NPS-SER Res./Resour. Mgmt. Rep. 54. Atlanta, GA: U.S. Department of the Interior, National Park Service. 31 p.

The influence of rooting by European wild boar (*Sus scrofa*) upon surface fauna, nutrients and biomass of forest litter and soil was investigated in the northern hardwood forest of Great Smoky Mountains National Park, 1979-1980. Two vertebrates that depend largely on leaf litter for habitat, the red backed vole (*Clethrionomys gapperi*), and short-tailed shrew (*Blarina brevicauda*), were nearly eliminated from intensely rooted stands. Rooting accelerated the leaching of Ca, P, Zn, Cu, and Mg from leaf litter and soil. Nitrate concentrations, however, were higher in soil, soil water, and stream water from the rooted stands, suggesting alterations in ecosystem nitrogen transformation processes.

525. **Singer, F. J.; Swank, W. T.; Clebsch, E. E. C. 1984.** Effects of wild pig rooting in a deciduous forest. Journal of Wildlife Management. 48: 464-473.

The influence of rooting by *Sus scrofa* on surface fauna, nutrients, and biomass of forest litter and soil was investigated in the Great Smoky Mountains National Park. Rooting by wild pigs mixed A1 and A2 soil horizons and reduced ground vegetative cover and leaf litter. Two vertebrates that depend largely on leaf litter for habitat, the southern red-backed voles and northern short-tailed shrews, were nearly eliminated from intensively rooted areas. Two other mammals and five salamanders that preferred more arboreal or subterranean habitats were unaffected by rooting. Rooting accelerated leaching of Ca, P, Zn, Cu, and Mg from leaf litter and soil. Nitrate concentrations were higher in soil, soil water, and stream water from the rooted areas suggesting alterations in nitrogen transformation processes. Rooting did not increase sediment yield, apparently because of the high infiltration rate of Southern Appalachian soils and because disturbance decreased bulk density.

526. **Sloan, P. G.; Moore, I. D.; Coltharp, G. B.; Eigel, J. D. 1983.** Modeling surface and subsurface stormflow on steeply-sloping forested watersheds. Res. Rep. 142. Lexington, KY. Water Resources Research Institute, University of Kentucky. 167 p.

A simple conceptual rainfall-runoff model, based on the variable source area concept, was developed for predicting runoff from small, steep-sloped, forested watersheds. Five subsurface flow models were evaluated with data from Coweeta soil model 3. Good agreement was shown between predicted daily discharges from the full model and field data from a test plot. The model simulated subsurface flow with the flashy hydrologic behavior of small watersheds.

527. **Sloan, Patrick G., Moore Ian D. 1984.** Modeling subsurface stormflow on steeply sloping forested watersheds. Water Resources Research. 20(12): 1815-1822.

Five mathematical models for predicting subsurface flow were compared to discharge measurements conducted by Hewlett and Hibbert (1963) on a uniform sloping soil trough. The models included one- and two-dimensional finite element models based on the Richards equation, a kinematic wave model, and two simple storage-discharge models based on the kinematic wave and Boussinesq assumptions. The simple models simulated the subsurface response and water-table positions as well as the more complex models based on the Richards equation and were much more economical to use from the point of view of computational costs. Such models have features that would allow them to be incorporated into more complex watershed models, thus placing hydrologic prediction on a more physically correct and less empirical footing.

528. **Sluder, Earl R. 1958.** Mountain farm woodland grazing doesn't pay. Res. Notes 119. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 2 p.

The general results of the mountain farm experiment at Coweeta are presented.

529. **Smith, James A.; Krajewski, Witold F. 1993.** A modeling study of rainfall rate-reflectivity relationships. Water Resources Research. 29(8): 2505-2514.

Power law models relate radar reflectivity to rainfall rate. Two interrelated problems are associated with these models: (1) estimation of parameters and (2) assessment of the accuracy of rainfall rate estimates. A statistical model provides explicit representations of power law model parameter estimates and the error of rainfall rate-reflectivity relationships in terms of raindrop processes. Empirical analyses use drop size data from a number of sites. Detailed analyses use a data set from Mooney Gap at Coweeta.

530. **Smith, Jeffrey. 1982.** At Coweeta. Emory Magazine. 59(1): 6-13.

A general article discussing aspects of Dr. Ragsdale's research at Coweeta.

531. **Smith-Cuffney, Francie L; Wallace, J. Bruce. 1987.** The influence of microhabitat on availability of drifting invertebrate prey to a net-spinning caddisfly. Freshwater Biology. 17: 91-98.

Invertebrate drift was sampled at both a rockface and a deep pebble-riffle site in streams draining both a clearcut and a forested catchment. A sampler was designed to separate the bottom 2 cm of flow, encompassing the effective range of caddisfly, from upper flow. No significant difference in drift density was seen between sites within each stream. However, numbers per square centimetre intake area per day at the rockface sites were 4 times higher in the clearcut and 10 times higher in the forested stream than at the pebble-riffle site. Rockface habitat which had highest drift availability was also the site of maximum secondary production of a predaceous collector-filterer in both streams studied. Increased sediment load in the clearcut stream may influence the efficiency of utilization of invertebrate drift by collector-filterers.

532. **Snyder, John E.; Hursh, Charles R. 1938.** Low cost erosion control on highway slopes in Southeastern United States. In: Erosion control. Proceedings of the 18th annual meeting of the Highway Research Board; 1938 December; Part 1: 213-215.

Important factors in stabilizing exposed highway slopes are the stability, moisture, and fertility of the soil. Steepness and length of slope, alternation of freezing and thawing, and the physical nature of soil affect soil stability. Lack of moisture because of overdrainage and direct exposure to solar radiation is also a basic cause of failure in road side naturalization. Many road cuts expose infertile subsoil and soil parent material which are difficult to vegetate. Use of mulches of local organic materials is a suitable means for ameliorating unfavorable site conditions.

533. **Southeastern Forest Experiment Station. 1948.** Watershed management research–Coweeta Experimental Forest. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 45 p.

This is the first guidebook to Coweeta and is designed to acquaint the reader with the Laboratory, the research methods, program, findings, and future research plans.

534. **Southeastern Forest Experiment Station. 1956.** We learn about little waters at Coweeta. The Forest Farmer. (16)2: 20-21.

Brief pictorial report of land management demonstrations at Coweeta.

535. **Southeastern Forest Experiment Station. 1961.** Watershed management. In: Report for 1961. Asheville, NC: U. S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 61-66.

Hewlett's variable source area concept was originally stated in this chapter of the Southeastern Station Annual Report.

536. **Southeastern Forest Experiment Station. 1964.** Improvements at Coweeta. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 16 p.

This report covers improvements and research at Coweeta since October 1962, when the Accelerated Public Works program began at the Laboratory. Improvements consisted of construction of a road and bridge in the administration area, a 20,000-gallon gravity water system, a three-bedroom dwelling for forest superintendents, a 40- by 60-foot metal warehouse for storage, a 40- by 100-foot wet lab, and an extension to the existing office building, as well as repairs made on 18 weirs and the reworking of 25 miles of neglected roads and trails. Research activities included installation of a 356-acre multiple use watershed and clearcutting of two forested watersheds to determine the effects on water yield.

537. **Southeastern Forest Experiment Station. 1968.** Visitor's guide - Coweeta Hydrologic Laboratory. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. [In-Serv. leafl.]

This leaflet enables the reader to make a self-guided tour of the Coweeta Hydrologic Laboratory.

538. **Southeastern Forest Experiment Station. 1984.** Coweeta Hydrologic Laboratory: a guide to the research program. Asheville, NC: U. S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

The guide is a popularized description of the research program and brief summary of key results. Prepared by Molly Swartz, Western Carolina University, Cullowhee, NC, for 50th anniversary of Coweeta.

539. **Southerland, Mark T. 1986.** The effects of variation in streamside habitats on the composition of mountain salamander communities. Copeia. (3): 731-741.

Three studies indicate that habitat affected interactions within the salamander community. Where more than 50 percent of the streambank possessed cover, two semiaquatic species occurred. Species composition of salamanders in different streams within the same watershed depended on whether one or two semiaquatic species were present. The semiaquatic *Desmognathus monticola* was found farther from water where the larger semiaquatic *D. quadramaculatus* was present. At a densely populated site, streambank burrows were monopolized by large desmognathines. Rocky or woody streambank cover increased the numbers of salamanders. Habitat differences along mountain streams are important in determining the structure of salamander communities because habitat moderates the effects of predation. These two semiaquatic species will coexist in the presence of abundant streambank cover, but may compete as adults for permanent burrows.

540. **Stagnitti, F.; Parlange, M. B.; Steenhuis, T. S.; Parlange, J.-Y. 1986.** Drainage from a uniform soil layer on a hillslope. Water Resources Research. 22(5): 631-634.

A simple hillslope hydrological model predicting discharge from sloping shallow soils is analyzed. Unlike most existing hillslope models, this model is fully analytic and thus straightforward to apply. It compares favorably to more complex models, and its application is illustrated for experimental data collected at the Coweeta Hydrologic Laboratory.

541. **Stanko, K. M.; Fitzgerald, J. W. 1990.** Chapter I. Sulfur transformations in forest soils collected along an elevational gradient. Soil Biology and Biochemistry. 22: 213-216.

^{35}S-labeled inorganic sulfate was incorporated into organic matter from A-horizon soils collected along an elevational gradient. These samples formed between 0.7 and 1.7 nmol S (as organic S)/g dry weight. Soils with higher moisture (65 percent) and high carbon content (8.4 percent) exhibited higher rates of organic S formation. Of the organic S generated, 33 to 44 percent was mineralized (mobilized) during 24 hours. Samples containing high concentrations of indigenous sulfate exhibited lower rates of mobilization and vice versa. Assays of samples collected over the gradient demonstrated that pH decreased as carbon content and sulfate adsorption (salt extractable S) increased. Total S, ester sulfate and inorganic sulfate content increased with increasing elevation.

542. **Stanko-Golden, K. M.; Fitzgerald, J. W.; Swank, W. T. 1992.** Sulfur processing in soil from high and low elevation forests in the Southern Appalachians of the United States. Soil Biology and Biochemistry. 24(7): 693-702.

Samples of A, E, and B horizons, collected from a high- and a low-elevation watershed, were analyzed for their capacity to adsorb sulfate, generate organic S and mobilize organic S. Sulfate adsorption potentials were significantly greater in soil from the high compared to that from the low-elevation watershed. Only A horizon samples from the two watersheds were statistically different in their capacity to synthesize organic S. Soil moisture, carbon, pH and S constituents were quantified and relationships between these variables and S-processing potentials were determined. A 60 to 70 percent increase in organic S formation rates was observed after amendment with cellobiose with samples from all horizons of the low-elevation watershed, indicating that soil from this watershed may be energy deficient in terms of organic S formation. Attempts were made to determine which S processes may be involved in ecosystem-level responses currently being observed with these watersheds.

543. **Stickney, Patricia L.; Swift, Lloyd W.; Swank, Wayne T., comp. 1994.** Annotated bibliography of publications on watershed management and ecological studies at Coweeta Hydrologic Laboratory, 1934-1994. Gen. Tech. Rep. SE-86. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 119 p.

This annotated bibliography spans over 60 years of research at Coweeta from 1934 through part of 1994, and includes earlier papers on forest influences written at the Appalachian Station before the establishment of Coweeta. It is a modification and update of previous compilations of research results at Coweeta and contains a separate section listing theses and dissertations. Papers were included if authors conducted research in the Coweeta Basin, utilized Coweeta data in their analyses, or were partially supported either with funding or assistance by the Southeastern Forest Experiment Station.

544. **Stiven, Alan E.; Bruce, Richard C. 1988.** Ecological genetics of the salamander *Desmognathus quadramaculatus* from disturbed watersheds in the Southern Appalachian Biosphere Reserve Cluster. Conservation Biology. 2(2): 194-205.

Ecological and genetic properties of the largely aquatic salamander, *D. quadramaculatus* were assessed in paired control and logged watersheds. Salamanders were larger but less abundant in watersheds of recently cut forest. Genetic diversity by electrophoretic analysis was lower where the time available for population recovery was least. Populations in undisturbed watersheds exhibited lower heterozygosity levels than those in logged watersheds. Confounding effects of elevation among watersheds were detected. An analysis of the six subpopulations showed moderate levels of genetic differentiation among the subpopulations. The genetic and ecological differences among populations between the two reserves are interpreted in terms of ecological theory.

545. **Stone, E. L.; Swank, W. T.; Hornbeck, J. W. 1980.** Impacts of timber harvest and regeneration systems on stream flow and soils in the eastern deciduous region. In: Forest soils and land use: Proceedings of the 5th North American forest soils conference; 1978 August; Fort Collins, CO. Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences: 516-535.

The review draws together the present understanding of how cutting in eastern deciduous forests for any of a variety of purposes affects soil and streamflow. Based on experimental results, generalizations are provided on responses in annual water yield and recovery after cutting, low flow, peak flow, soil moisture, stream temperature, sedimentation, and nutrients.

546. **Stout, Ben M., III; Benfield, E. F.; Webster, J. R. 1993.** Effects of a forest disturbance on shredder production in southern Appalachian headwater streams. Freshwater Biology. 29: 59-69.

Production of leaf-shredding aquatic insects was compared in streams draining mature hardwood forest and streams draining an 11-year-old, cable-logged clearcut. Reference streams contained greater annual standing crop of leaf material and more slow-processing leaf material than disturbed streams. Disturbed streams had a higher annual standing crop of fast-processing leaf material. Leaf-shredding cranefly, caddisfly, and stonefly larvae comprised over 95 percent of shredder biomass in all streams. Total shredder production was greater in disturbed streams. Caddisfly larvae were present at higher densities and greater annual biomass in disturbed streams. This biomass was correlated with the standing crop of fast processing, early successional leaf material, whereas biomass of other shredders was correlated with medium- or slow-processing leaf species characteristic of later stages of forest succession.

547. **Stout, Glenn E.; Mueller, Eugene A. 1968.** Survey of relationships between rainfall rate and radar reflectivity in the measurement of precipitation. Journal of Applied Meteorology. 7(3): 465-474.

Raindrop-size distributions measured at Coweeta and eight other locations were used to derive a relationship between rainfall intensity and radar reflectivity for the purpose of using radar to estimate rainfall amount. Between geographic locations, rainfall rate varied 500 percent for the same reflectivity. Differences of 150 percent were attributed to storm type. At each site, differences within a storm were minor. For a given storm type at a specific location, errors in measurement of radar reflectivity are greater than errors of estimating rainfall from reflectivity.

548. **Strickland, T. C.; Fitzgerald, J. W. 1983.** Mineralization of sulphur in sulphoquinovose by forest soils. Soil Biology and Biochemistry. 15(3): 347-349.

Surface soils from four watersheds located in the Coweeta Basin near Franklin, NC, were assayed for their capacity to mineralize sulphur in 6-sulphoquinovose. All soils rapidly converted S in this component of the plant sulpholipid to inorganic sulphate, a soluble (salt extractable) ester sulphate and an insoluble ester sulphate. Sulphur in this latter fraction was released by acidhydrolysis of soil residues at 121 °C. Although maximum concentrations of S in each fraction varied with duration of incubation, rates of conversion of S into all fractions were highest during the first hour. Mineralization rates based upon sulphate release and total S released from sulphoquinovose are reported.

549. **Strickland, T. C.; Fitzgerald, J. W. 1984.** Formation and mineralization of organic sulfur in forest soils. Biogeochemistry. 1: 79-95.

Incorporation of sulfur into organic matter was examined using ^{35}S in O1, O2 and A-horizon samples from two hardwood forests. This temperature-dependent transformation was stimulated by increased availability of sulfate or energy. The process was inhibited by sodium azide, erythromycin and candicidin. Bacteria and fungi mediate sulfur incorporation via the formation of covalent linkages. Incorporated sulfur is subject to mineralization after depolymerization of the carbon matrix; methods are given for direct and indirect assessment of potential turnover rates. The availability of sulfate from mineralization appears to depend upon the rate of incorporation of sulfur into organic matter. Substantially higher levels of extractable sulfate were detected when turnover of the isolated organosulfur fraction was assayed for in the presence of axide, an inhibitor of sulfate incorporation. However, the reverse was true when turnover was monitored in the presence of glucose and succinate which stimulate sulfate incorporation.

550. **Strickland, T. C.; Fitzgerald, J. W. 1986.** Organosulphur recalcitrance in soil and litter from a hardwood forest. Soil Biology and Biochemistry. 18(6): 661-662.

Accumulation of sulphate S in forested watersheds is mediated physically by sulphate adsorption and microbially by incorporation of sulphur into covalent linkage with soil organic matter. In turn, some recently formed insoluble organic S may also be converted to soluble forms. But organic S in humic acid may be resistant to degradation. We determined the change in organic S mobilization capacity of samples as a function of the time required for organic S to be formed from sulphate. Results suggest that condensation of S components into the humic core results in making organic S mineralization dependent upon humus degradation rates. Organic S in soil can be expected to participate in humus formation in the same way as any other organic component of the solum. Biologically mediated cyclization and polymerization of organic material will in time increase the net recalcitrance of the organic material to microbial attack.

551. **Strickland, T. C.; Fitzgerald, J. W. 1987.** Bacterial production of organic sulphur in a forest litter extract. Soil Biology and Biochemistry. 19(6): 771-774.

Field studies have demonstrated that organic sulphur is accumulated into organic matter in soil and litter of deciduous forests, and indirect evidence suggests that the process is microbially mediated. The aim of our study was to show the direct involvement of soil micro-organisms in organic-S formation. Direct evidence for bacterial involvement is provided, since incubation of a Gram-negative soil isolate with $^{35}SO_4$ produced two electrophoretically-separable species of organic-S which exhibited the same mobilities as those found in earlier studies. Compared with the rate of organic-S formation from sulphate, the very low rates of formation observed

when the ^{35}S-labeled organic-S precursors $AP^{35}S$ or $PAP^{35}S$ were used as the S source indicate no extracellular sulphotransferase activity in the media and that the "active sulphate" components must first be transported into the cell or mineralized to sulphate before S uptake and organic-S synthesis.

552. **Strickland, T. C.; Fitzgerald, J. W.; Swank, W. T. 1984.** Mobilization of recently formed forest soil organic sulfur. Canadian Journal of Forest Research. 14: 63-67.

Soils from a mixed mature hardwood forest were assayed for their capacity to mobilize sulfur that had been previously immobilized into a non-salt-extractable (insoluble) form. These soils rapidly released soluble organic sulfur and inorganic sulfate from this fraction. It is suggested that the former component is a depolymerization product of a more complex organic sulfur matrix. The activity of preformed extracellular depolymerase and sulfohydrolase enzymes in the soil may be responsible for the depolymerization and subsequent desulfation of the organic sulfur matrix. This is supported by observations that treatment of soil samples with sodium sulfate, sodium azide, erythromycin, or candicidin failed to inhibit the capacity of A1-horizon soils to mobilize the organic sulfur fraction. The rates and final levels of sulfur mobilization increased with an increase in temperature and decreased with sample depth.

553. **Strickland, T. C.; Fitzgerald, J. W.; Swank, W. T. 1986.** In situ mobilization of ^{35}S-labelled organic sulphur in litter and soil from a hardwood forest. Soil Biology and Biochemistry. 18(5): 463-468.

^{35}S-labeled inorganic sulphate was incorporated into the organic matter of an extract from 02 horizon litter to yield an organic-S preparation of high specific radioactivity. In the labeled organic-S preparation, 13, 47, and 40 percent of the total S was present as ester sulphate, amino acid-S and sulphonate-S, respectively. The in situ mobilization of this organic-$S0_3$ preparation was monitored during field incubations with surface horizons of a hardwood forest.

554. **Strickland, Timothy C.; Fitzgerald, John W. 1985.** Incorporation of sulphate-sulphur into organic matter extracts of litter and soil: involvement of ATP sulphurylase. Soil Biology and Biochemistry. 17(6): 779-784.

Organic matter extracts from the 01, 02 and A1 horizons of a hardwood forest rapidly incorporated labeled sulphate into organic sulphur components. In the 02 layer extract, the ^{35}S-label was incorporated into amino acid-S, sulphonate-S and ester sulphate linkages. This process was stimulated by adenosine 5'-triphosphate (ATP), cellulose, cellobiose, glucose, succinate and pyruvate. The involvement of ATP sulphurylase, elaborated by bacteria present in this extract, is suggested by observations that incorporation was also stimulated by Mg^2 ions and inhibited by erythromycin, tetracycline, sodium azide, selenate, molybdate and chlorate. ^{35}S-labeled adenosine 5'-phosphosulphate or 3'-phosphoadenosine-5'-phosphosulphate also served as S donors for organic-S formation but the rate of organic-S formation was much lower than that observed when ^{35}S-sulphate was the S donor.

555. **Strickland, Timothy C.; Fitzgerald, John W.; Ash, Jaru T.; Swank, Wayne T. 1987.** Organic sulfur transformations and sulfur pool sizes in soil and litter from a Southern Appalachian hardwood forest. Soil Science. 143(6): 453-458.

Soil samples from a mixed mature hardwood forest were assayed for the capacity to incorporate sulfate-sulfur into organic matter and for the capacity to subsequently mobilize the organic sulfur formed. We found seasonal variation in sulfur pool sizes, transformation rates between inorganic and organic sulfur, and in transformation rates among the organic sulfur pools. Higher incorporation rates were observed with higher contents of carbon-bonded S. Amounts of this form of sulfur may reflect the level of readily available carbon and energy. When ester sulfate contents were low, organic S mobilization rates were elevated and free and adsorbed S pools increased. These observations suggest that ester sulfate in soil may serve as an important supply of sulfur for biological uptake.

556. **Strickland, Timothy C.; Fitzgerald, John W.; Swank, Wayne T. 1986.** In situ measurements of sulfate incorporation into forest floor and soil organic matter. Canadian Journal of Forest Research. 16: 549-553.

Litter and soil from a mixed mature hardwood forest were examined for the capacity to incorporate ^{35}S-labeled sulfate into organic matter in situ. Amounts of sulfate incorporated within 48hours of field incubation were 70, 49, and 18 percent of added ^{35}S per gram of substrate in the O1, O2, and A horizons, respectively. These potentials increased in the respective horizons to 74, 61, and 29 percent after 7 days. The incorporated ^{35}S was predominately in the form of carbon-bonded S. In situ incorporation rates exceeded rates previously estimated by laboratory incubations and the former rates showed a positive response to increased sulfate loading.

557. **Stroud, R. H. 1965.** $P = (T + I + E) + R \pm \Delta S$. *In*: Sport Fishing Institute Bulletin 160, March 1965: 4-7.

This popular-style report describes results from the first 30 years of Coweeta research, emphasizing water yield, land use, and soil model studies. Conclusions promote continuation and expansion of the research program at Coweeta Lab field site.

558. **Suberkropp, Keller; Wallace, J. Bruce. 1992.** Aquatic hyphomycetes in insecticide-treated and untreated streams. Journal of the North American Benthological Society. 11(2): 165-171.

Both shredder abundances and production were dramatically reduced in a small headwater stream by the insecticide methoxychlor. The aquatic hyphomycete assemblage was compared with the assemblages in two

reference streams containing high abundances of insect shredders. Concentrations of conidia being transported in the water of the treated stream were higher than those in the reference streams during much of the year, but the species composition was similar among the three streams.

559. **Swank, W. T. 1968.** The influence of rainfall interception on streamflow. In: Proceedings, hydrologic water resource management conference; 1968 March 28-29; Clemson, SC. Clemson, SC: Clemson University Water Resources Research Institute. report 4: 101-112.

The data presented provide evidence that interception loss is a major hydrologic process which reduces the quantity and alters the timing of streamflow from watersheds in the Southern Appalachians when cover types are changed from mature mixed hardwoods to eastern white pine. Differences in interception loss between loblolly pine and mature hardwoods in the Piedmont of South Carolina are discussed.

560. **Swank, W. T. 1972.** Soils and water. In: Wade, Larkin, ed. Social and political influence in the managed forest: Proceedings of the 11th Auburn forestry forum; 1972 December; Auburn, AL. Auburn, AL: Cooperative Extension Service, Auburn University: 51-58.

This paper reviews the impacts of forest cutting on water yield, timing, water quality, and soil nutrients for some forest ecosystems in the Eastern United States.

561. **Swank, W. T. 1981.** Models in forest hydrology, an overview. In: Proceedings, IUFRO workshop on water and nutrient simulation models; 1979 August 27-September 1; Birmensdorf, Switzerland; Zurich, Switzerland. Birmensdorf: Swiss Federal Institute of Forestry Research: 13-20.

This paper summarizes the development of forest hydrology models from programmatic and technical viewpoints.

562. **Swank, W. T. 1988.** Stream chemistry responses to disturbance. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 339-357.

The vegetation on 12 watersheds at Coweeta has been altered by experimentation during the past 50 years. Disturbances include commercial selection cutting, commercial and noncommercial clearcutting, conversion of mixed hardwoods to white pine and grass covers, agricultural cropping, and natural disturbances of insect outbreaks. None of the disturbances produced nutrient concentrations that would have an adverse impact on water quality for municipalities or downstream fisheries. Nitrate-N is a sensitive indicator of forest disturbance, and elevated, but low, concentrations in streams draining clearcuts appear to persist for at least 20 years after cutting. Hardwood to white pine conversion increased evapotranspiration, reduced annual stream discharge, and consequently reduced the export of some dissolved nutrients. Conversely, clearcutting reduced evapotranspiration, increased water flux, and increased nutrient export.

563. **Swank, W.T.; Bolstad, P.V. 1994.** Cumulative effects of land use practices on water quality. In: Peters, N.E.; Allan, R.J.; Tsirkunov, V.V., eds. Hydrochemistry 1993: hydrological, chemical and biological processes affecting the transformation and transport of contaminants in aquatic environments: Proceedings of the Rostov-on-don symposium; May 1993; IAHS Publ. 219. Oxfordshire, UK: IAHS Press: 409-421.

Trends in water-quality parameters (ions, pH, turbidity, conductivity, temperature, faecal and total coliform bacteria, and faecal streptococcus) within a Southern Appalachian stream-order gradient were related to cumulative changes in landscape variables. Water samples collected bi-weekly at six stations along a first- to fifth-order stream gradient, and landscape variables (hydrography, landcover, roads, slope, surficial geology, bedrock geology, soils) were mapped for the contributing watersheds above each station. Water quality was high under baseflow conditions in the predominantly forested study area, with solute concentrations usually less than 1 mg l^{-1} and turbidity values less than 3 NTU, with small, consistent increases downstream. In contrast, large, steep gradients in water-quality parameters were observed under stormflow conditions, in some cases increasing three to six times. A number of water-quality parameters (Cl^-, K^+, Na^+, Ca^+, Mg^+, SO_4^{2-}, SiO_2, turbidity, faecal streptococcus, and faecal coliform) exhibited significant linear relationships with a number of landscape variables (percentage of nonforest, structure density, and paved road density).

564. **Swank, W. T.; Crossley, D. A.,Jr. 1986.** Coweeta Hydrologic Laboratory background and synthesis. In: Dyer, M. I.; Crossley, D. A., Jr., eds. Coupling of ecological studies with remote sensing: potentials at four Biosphere Reserves in the United States. Publ. 9504. Washington, DC: U.S. Department of State, Man and the Biosphere Program: 23-32.

This paper gives a historical sketch, site characteristics, and a general description of the Biosphere Reserve at Coweeta Hydrologic Laboratory, North Carolina. Up-to-date assessment of production values, water chemistry, and physical characteristics of the numerous experimental and control watersheds are provided.

565. **Swank, W. T.; Crossley, D. A., Jr. 1988.** Introduction and site description. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 3-16.

This chapter introduces a 30-chapter book describing results of a variety of research efforts with forested catchments at Coweeta Hydrologic Laboratory. The site was established 50 years ago as a testing ground for certain theories in forest hydrology. The research program at Coweeta represents a continuum of theory, experimentation, and application using watersheds as

landscape units. The volume begins with descriptions of the Coweeta Basin, various watershed treatments and available resource inventories.

566. **Swank, W. T.; Douglass, J. E. 1975.** Nutrient flux in undisturbed and manipulated forest ecosystems in the southern Appalachian Mountains. In: Proceedings of the Tokyo symposium on the hydrological characteristics of river basins and the effects on these characteristics of better water management; 1975 December; Tokyo, Japan. Washington, DC: International Association of Hydrological Science: 445-456.

Nutrient concentrations in stream water were studied on 8 mature hardwood ecosystems and 16 altered forested systems. The budget of NO_3-N, NH_4-N, PO_4-P, Cl, K, Na, Ca, Mg, and SO_4 was derived for 14 watersheds. Compared with undisturbed watersheds, a grass-to-forest succession watershed that had been fertilized, limed, and herbicided showed larger losses of ions except for PO_4-P. Elevated NO_3-N discharge was evident at least 10 years after cutting, but appeared to return to baseline levels 20 years after treatment. Conversion of hardwoods to white pine reduced the loss of most nutrients. No changes in the discharge of NH_4-N and PO_4-P were observed for any of the watersheds; all ecosystems showed very large accumulations of SO_4.

567. **Swank, W. T.; Douglass, J. E. 1977.** Nutrient budgets for undisturbed and manipulated hardwood forest ecosystems in the mountains of North Carolina. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 343-364.

Stream chemistry was monitored for 8 mature hardwood ecosystems and 16 altered forested systems. Net budgets of NO_3-N, NH_4-N, PO_4-P, Cl, K, Na, Ca, Mg, SO_4, and SiO_2 were estimated for 15 ecosystems. Nitrate-Nitrogen was most sensitive to disturbance. When forests were cut, NO_3-N discharge was elevated for at least 13 years. No changes in the discharge of NH_4-N and PO_4-P were observed for any of the watersheds; all ecosystems showed very large accumulations of SO_4. A grass-to-forest succession watershed that had been fertilized, limed, and herbicided showed large nutrient losses. Conversion of hardwoods to white pine reduced the loss of most nutrients.

568. **Swank, W. T.; Douglass, J. E.; Cunningham, G. B. 1982.** Changes in water yield and storm hydrographs following commercial clearcutting on a Southern Appalachian catchment. In: Hydrological research basins and their use in water resource planning: Proceedings of the international symposium; 1982 September 21-23; Berne, Switzerland. Berne, Switzerland: National Hydrologic Service: 583-594. Vol. 2.

The first year after commercial clearcutting and cable logging in a mixed hardwood forest, annual streamflow from a 59-ha catchment increased 26 cm. The experimental response in flow was within 4 percent of the value predicted from a regional model. During the first 4 years of regrowth, the model prediction was within 15 percent of the 72-cm total change in water yield. The largest measured changes in monthly flow occurred during the lowest flow months. Storm hydrograph analysis showed that, on the average, initial flow rate and peakflow rate increased about 15 percent and stormflow increased 10 percent. The treatment effect was greatest for small storms, and the alteration of storm hydrograph parameters was judged to be of minor importance in management planning.

569. **Swank, W. T.; Fitzgerald, J. W.; Strickland, T. C. 1987.** Microbial incorporation of sulfate into organic matter in forest soils. In: Swanson, R. H.; Bernier, P. Y.; Woodard, P. D., eds. Forest hydrogology and watershed management: Proceedings of an international symposium held during the 19th General Assembly of the International Union of Geodesy and Geophysics; 1987 August 9-22; Vancouver, BC: IAHS-AISH Publ. 167. Oxfordshire, UK: IAHS Press: 3-10.

The metabolism of inorganic sulfate into organic matter by microbial populations can be an important process in the sulfur cycle of forest ecosystems. Potential annual incorporation in forest floor and soil horizons was estimated. The process is partially responsible for the apparent sulfur accumulation indicated by ecosystem budgets and affects sulfate mobility, cation leaching, and hence the interpretation of atmospheric sulfuric acid effects on forest ecosystems.

570. **Swank, W. T.; Helvey, J. D. 1970.** Reduction of streamflow increases following regrowth of clearcut hardwood forests. In: Symposium on the results of research on representative and experimental basins; 1970 December; Wellington, New Zealand. Publication 96. Leuven, Belgium: United Nations Educational, Scientific and Cultural Organization - International Association of Scientific Hydrology: 346-360.

The mature hardwood forest on a 16-ha catchment at the Coweeta Hydrologic Laboratory was initially clearcut in 1939. The first year following cutting, streamflow increased 360 mm. As the even-aged coppice stand regrew, annual streamflow increases approached pretreatment levels as a linear function of the logarithm of time. The watershed was clearcut again in 1962, and streamflow response for the year following cutting was 380 mm. In striking contrast to the first cutting, streamflow increases have diminished at a much faster rate, and it appears that annual water yield will return to pretreatment levels after just 16 years of forest regrowth following the second cutting. The difference in the measured response is attributed primarily to a more rapid recovery of vegetation in the second treatment period.

571. **Swank, W. T.; Miner, N. H. 1968.** Conversion of hardwood-covered watersheds to white pine reduces water yield. Water Resources Research. 4: 947-954.

Mixed mature hardwoods were cleared from two experimental watersheds in the Southern Appalachians, and the areas were planted with eastern white pine in

1956 and 1957. Once the pine crowns began to close, streamflow steadily declined at a rate of 1 to 2 inches per year. By 1967, water yield from a 10-year-old pine stand on a south-facing watershed was 3.7 inches less than the expected water yield from the original hardwood forest. Most of the reduction in water yield occurred during the dormant season and was attributed mainly to greater interception loss from white pine than from hardwoods. Because interception differences increase as white pine matures, an even greater reduction in streamflow is expected.

572. **Swank, W. T.; Schreuder, H. T. 1973.** Temporal changes in biomass, surface area and net production for a *Pinus strobus* L. forest. In: International Union of Forest Research Organizations biomass studies, working party on the mensuration of forest biomass, S4.01 mensuration growth and yield; 1973 June 25-29; Nancy, France; 1973 August 20-24; Vancouver, Canada. Orono, ME: University of Maine, College of Life Science and Agriculture: 173-182.

Weighted, linear regression models were used to estimate biomass and surface area of foliage, branches, and stems from tree basal area for a planted white pine stand on a 16.1-ha watershed. Estimates were made at stand ages 10, 12, and 15 years. During the 5-year period, the stand closure changed from partial to complete and model coefficients showed large changes, particularly for foliage. In February 1972, aboveground biomass for the population was 4664, 22825, and 42110 kg/ha for foliage, branches, and stems. The population of trees contained 9.9, 2.3, and 0.4 ha of foliage, branches, and stems per ha of land surface. Net primary production was estimated to be 13500 kg/ha/year, and foliage development for the pine population culminated when the stand was only 12 years old.

573. **Swank, W. T.; Swift, L. W., Jr.; Douglass, J. E. 1988.** Streamflow changes associated with forest cutting, species conversions, and natural disturbances. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 297-312.

An original research objective in the establishment of Coweeta was to measure and evaluate the effects of man's use of the forest on the quantity and timing of streamflow. Fifteen individual watershed-scale experiments have been conducted in the basin, involving various intensities of forest cutting and harvest and conversions of hardwood forest to white pine or grass. The purpose of this chapter is to provide a synthesis of findings on (1) responses in annual and monthly streamflow quantities following cutting, species conversions, and natural disturbance; (2) changes in storm hydrograph characteristics that accompany clearcutting; and (3) the application of results to water resources planning on forested watersheds.

574. **Swank, W. T.; Waide, J. B. 1980.** Interpretation of nutrient cycling research in a management context: evaluating potential effects of alternative management strategies on site productivity. In: Waring, Richard W., ed. Forests: fresh perspective from ecosystem analysis; 1979 April 27; Corvallis, OR: Oregon State University Press: 137-158.

This paper evaluates the effects of various harvesting practices and alternative levels of wood-fiber utilization on the sustainable productivity of forests. The analysis includes three phases: (1) characterization of ecosystem nutrient budgets for several contrasting forest ecosystems in different physiographic regions of the United States; (2) examination of nutrient pools contained within ecosystem compartments, and annual transfer rates among compartments; and (3) elaboration of the conceptual model framework which has guided ecosystem research at Coweeta Hydrologic Laboratory, and illustration of how specific data sets can be used to determine important management needs.

575. **Swank, W. T.; Waide, J. B. 1988.** Characterization of baseline precipitation and stream chemistry and nutrient budgets for control watersheds. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 57-79.

The Coweeta precipitation and stream chemistry record is among the most extensive, long-term data bases available for any single location. Objectives of this chapter are to summarize the long-term record of Basin precipitation and stream chemistry for control watersheds. Specifically, it (1) evaluates the sampling network, (2) characterizes the average solute composition of precipitation and stream water for select watersheds, (3) describes long-term annual and seasonal trends of specific solutes, and (4) describes average annual nutrient budgets for control watersheds.

576. **Swank, W. T.; Waide, J. B.; Crossley, D. A., Jr.; Todd, R. L. 1981.** Insect defoliation enhances nitrate export from forest ecosytems. Oecologia. 51: 297-299.

Chronic defoliation by the fall cankerworm, *Alsophila pometaria* (Harris), accompanied substantial increases in the stream export of nitrate nitrogen (NO_3-N) from three mixed hardwood forests in the Southern Appalachians. These integrated results clearly demonstrate a measurable effect of insect consumers on ecosystem processes, and provide support for the regulatory importance of insects on a landscape scale.

577. **Swank, Wayne T. 1978.** Ecosystem studies program. In: Environmental biology. National Science Foundation Program Report (2)4. Washington, DC: National Science Foundation: 33-46.

This paper traces the development of the Ecosystem Studies Program at the National Science Foundation from its early development through 1978 with illustrations and examples of contributions to ecosystem science.

578. **Swank, Wayne T. 1981.** Review of biogeochemical cycling of mineral-forming elements: studies in

environmental science; vol. 3. Quarterly Review of Biology. 56: 91.

A book review.

579. **Swank, Wayne T. 1982.** Studi di ecologia e idrologia forestali. Padova, Italy: Universaita di Padova, Instituto di Ecologia e Selvicoltura. 103 p.

This document is a series of lectures presented at the Institute of Ecology and Silviculture of the University of Padova, Italy. The lectures are organized into four main topics: (1) biogeochemical cycling in forest ecosystems, (2) effects of forest management practices on quality and timing of streamflow, (3) water-quality and management practices, and (4) impact of site preparation on soil and water characteristics.

580. **Swank, Wayne T. 1984.** Atmospheric contributions to forest nutrient cycling. Water Resources Bulletin. 20(3): 313-321.

The atmosphere is a significant source of plant nutrients that partially replenishes losses due to timber harvesting. Nitrogen in bulk precipitation (wetfall and dryfall) is equivalent to at least 70 percent of the nitrogen incorporated annually in aboveground woody tissues of some temperate hardwood forests. Atmospheric sources of calcium and potassium supply between 20 and 40 percent of the nutrients sequestered in woody increments. Annual nutrient inputs in bulk precipitation can exceed removals associated with sawlog harvest over a rotation period. Atmospheric inputs of nitrogen are only slightly less than hydrologic losses immediately after timber harvesting. The deposition of nutrients is highly variable in both time and space; interpretations of nutrient inputs and forest management impacts require quantification of inputs for a variety of ecosystems over long periods of time.

581. **Swank, Wayne T. 1986.** Biological control of solute losses from forest ecosystems. In: Trudgill, S.T., ed. Solute processes. New York: John Wiley & Sons: 85-139.

The objective of this chapter is to identify and demonstrate the influence of selected biotic factors on solute movement in both terrestrial and stream ecosystems. The reader should recognize the complexity of quantitatively separating physical, chemical, and biological factors of solute behavior. The approach taken uses small catchments (8 to 60 ha) as the unit of investigation. Emphasis will be placed on biological controls which can be inferred or illustrated by landscape-scale experiments and/or recent, original biological process research.

582. **Swank, Wayne T. 1991.** Nitrogen transformation processes in selected forest ecosystems of the Great Smoky Mountains National Park. In: Ffolliott, Peter F.; Swank, Wayne T., eds. People and the temperate region: a summary of research from the United States Man and the Biosphere Program 1991. Publication 9838. Washington, DC: U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs: 11-14. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161; PB 91-126813]

Nitrogen transformation data have been unavailable for the Great Smoky Mountains National Park. This study was designed to quantify the rates of free-living nitrogen fixation, potential mineralization, and potential nitrification in the forest floor and soil compartments of old-growth and aggrading forest stands, and to compare the rates of these nitrogen transformation processes in forests disturbed by wild-pig rooting.

583. **Swank, Wayne T.; Caskey, William H. 1982.** Nitrate depletion in a second-order mountain stream. Journal of Environmental Quality. 11: 581-584.

The amount of NO_3-N exported in a second-order mountain stream draining a clearcut and logged mixed-hardwood forest was studied over a 4-year period. Calculations based on measurements of stream chemistry and discharge rates indicated a within-stream depletion of NO_3 from the upper reaches of the stream to the watershed outlet. Within-stream depletion the first year of treatment was 127 percent of total NO_3-N discharged from the watershed outlet and declined in succeeding years after treatment to 99, 42, and 5 percent. Assays of the quantities of denitrifying enzymes in stream sediment samples suggested 1.7 kg N/yr were lost via this pathway, compared with 3.9 kg N/yr calculated from within-stream depletion for the same time period. This study suggests sediment denitrification is a major pathway by which NO_3-N is lost.

584. **Swank, Wayne T.; Crossley, D. A., Jr., eds. 1988.** Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag. 469 p.

This book is based on presentations at a 3-day symposium held in Athens, GA, in October 1984 to commemorate 50 years of research at the Coweeta Hydrologic Laboratory. It reviews and summarizes hydrologic and ecological responses of baseline and managed Southern Appalachian forests at one of the oldest continuously operating laboratories of its kind in the world. This long-term approach represents a continuum of theory, experimentation, and application using watersheds as landscape units of investigation. The information encompasses a wide range of interpretations and interests and highlights major contributions from Coweeta to hydrologic and ecological understanding of Southern Appalachian forested lands. The 30 chapters provide a foundation of knowledge and baseline information essential to the future synthesis of ecosystem research at the site.

585. **Swank, Wayne T.; DeBano, Leonard F.; Nelson, Devon. 1989.** Effects of timber management practices on soil and water. In: Burns, Russel L., tech. comp. The scientific basis for silvicultural and management decisions in the national forest system. Gen. Tech. Rep. WO-55. Washington, DC: U.S. Department of Agriculture, Forest Service: 79-106.

This paper summarizes what is known, in the United States, about the effects of various forest management practices on soil and water characteristics. The collective body of scientific knowledge on this topic is extensive and represents the most complete factual research available in the world. Seven decades of research by the Forest Service, universities, and private industry provide a firm foundation for evaluating impacts at different regional levels. In some instances, information is incomplete, poorly understood, or so variable that generalizations are not possible at this time; these situations are identified in the text.

586. **Swank, Wayne T.; Douglass, James E. 1974.** Streamflow greatly reduced by converting deciduous hardwood stands to pine. Science. 185: 857-859.

Fifteen years after two experimental watersheds in the Southern Appalachians had been converted from a mature deciduous hardwood cover to white pine, annual streamflow was reduced about 20 cm (20 percent) below that expected for the hardwood cover. Streamflow was reduced during every month, with the largest monthly reductions (1.5 to 3.5 cm) occurring in the dormant and early growing seasons.

587. **Swank, Wayne T.; Fitzgerald, John W.; Ash, Jaru T. 1984.** Microbial transformation of sulfate in forest soils. Science. 223: (4632)182-184.

Incubation of forest soils containing sulfate labeled with sulfur-35 showed rapid conversion of the added sulfate to organic sulfur forms by microbial populations. Activity rates were highest in the forest floor, but significant activity was observed throughout the soil profile. The annual potential sulfur incorporation for forest floor and soil combined is estimated to be 30 kg/ha. The metabolism of inorganic sulfate to organic forms can be a major process in the sulfur cycle, influencing sulfate accumulation and mobility in forest ecosystems.

588. **Swank, Wayne T.; Fitzgerald, J. W.; Strickland, T. C. 1985.** Transformations of sulfur in forest floor and soil of a forest ecosystem. In: Johansson, Irene, ed. Hydrological and hydrogeochemical mechanisms and model approaches to the acidification of ecological systems: International Hydrological Programme (IHP) workshop; Nordic Hydrological Programme NHP report 10; 1984 September 15-16; Uppsala, Sweden; Oslo, Norway: Nordic National Committees for Hydrology: 137-145.

Incubation of forest floor and soils containing sulfate labeled with ^{35}S showed rapid metabolism of the added sulfate to organic sulfur forms by microbial populations. Rates of incorporation were regulated by exogenous sulfate concentrations and temperature. Mobilization experiments also using a ^{35}S label showed substantial release of incorporated sulfur. Initial results indicate that incorporation rates exceed mobilization rates resulting in a net accumulation of organic sulfur in the soil. This is reflected in watershed budgets which show net sulfate accumulations. These transformation processes are dynamic and strongly influence the supply and mobility of sulfate in soil solution which is important in understanding the impact of acid precipitation on leaching losses of ions.

589. **Swank, Wayne T.; Goebel, Norbert B.; Helvey, Junior D. 1972.** Interception loss in loblolly pine stands of the South Carolina Piedmont. Journal of Soil and Water Conservation. 27: 160-164.

Annual interception loss was measured in 5-, 10-, 20- and 30-year-old loblolly pine stands and in a mature hardwood-pine forest in the Piedmont of South Carolina. Interception loss for the loblolly pine stands was estimated to be 14, 22, 18, and 18 percent of annual precipitation (54 inches). Annual interception loss from the hardwood-pine stand was similar to that of the pine stands. However, on the average, the loss of water intercepted annually by loblolly pine appeared to be about 4 inches greater than the loss estimated from a number of hardwood studies. Where extensive conversions of hardwood to loblolly pine occur, significant reductions in the amount of water available for streamflow or ground water should be expected.

590. **Swank, Wayne T.; Henderson, Gray S. 1976.** Atmospheric input of some cations and anions to forest ecosystems in North Carolina and Tennessee. Water Resources Research. 12: 541-546.

Contributions to forest ecosystems of ions in precipitation and dry fallout were measured at two sites in the Southern Appalachians. Relative mean annual concentrations of cations in bulk precipitation were: Ca > Na > K > Mg. At Coweeta, average annual inputs of Ca, Na, K, Mg, and NH_4-N from 1970 to 1973 were 4.88, 3.52, 1.62, 1.01, and 0.52 kg/ha/yr. At Walker Branch, the inputs were 15.73, 3.89, 2.99, 2.94, and 2.37 kg/ha/yr. The inputs of NO_3-N, PO_4-P, and Cl in 1972-1973 were 2.88, 0.19, and 8.53 kg/ha/yr at Coweeta, while NO_3-N and PO_4-P were 4.61 and 0.55 kg/ha at Walker Branch. One reason for differences was greater dry fallout for some cations at Walker Branch than at Coweeta. For both sites, dry fallout associated with local land use activities influenced seasonal concentrations of bulk precipitation. Na appeared to be partly derived from marine sources.

591. **Swank, Wayne T.; Reynolds, Barbara C. 1986.** Within-tree distribution of woody biomass and nutrients for selected hardwood species. In: Brooks, Robert T., Jr., ed. Proceedings of the 1986 Southern forest biomass workshop; 1986 June 16-19; Knoxville, TN. Norris, TN: Tennessee Valley Authority: 87-91.

Detailed biomass and nutrient analyses were conducted on 14 trees representing 3 important hardwood taxa as part of a study to evaluate ecosystems effects of whole-tree harvesting in the Southern Appalachians.

592. **Swank, Wayne T.; Reynolds, L. J. 1987.** Analysis of dry and wet deposition, throughfall, and stemflow event chemistry in a *Pinus strobus* L. plantation. In: Acidification and water pathways; 1987 May 4-5; Bolkesjo, Norway. Oslo, Norway: Norwegian National Committee for Hydrology: 127-136.

A study site established in a 30-year-old white pine stand is part of the Integrated Forest Effects Project to examine the impacts of atmospheric deposition on forest element cycles. Measurements of chemical constituents in the atmosphere, precipitation, throughfall, and stemflow were made during early spring of 1986. Atmospheric concentrations of constituents were comparable to concentrations observed during the same period in two other participating study sites in the region. Wet-only fluxes for select events in the pine stand indicate that canopy leaching was a major process of base cation and possibly other ion deposition to the forest floor during the period of study.

593. **Swank, Wayne T.; Schreuder, Hans T. 1974.** Comparison of three methods of estimating surface area and biomass for a forest of young eastern white pine. Forest Science. 20: 91-100.

Foliage, branch and stem surface area, and ovendry weight, with estimates of precision of these statistics are presented for a 10-year-old stand of eastern white pine on a 16-ha watershed at the Coweeta Hydrologic Laboratory. Three different methods were used to estimate the forest surface area and biomass: (1) stratified two-phase sampling, (2) two-phase sampling with a regression estimator, and (3) two-phase sampling with a ratio-of-means estimator. Stratified two-phase sampling was the most precise and appropriate method; the population was estimated to contain 5.3 ha foliage, 0.76 ha branches, and 0.13 ha stems per hectare of land surface. The estimated ovendry weight of tree components was estimated to be 2.71, 6.83, and 7.01 metric tons per hectare, respectively, for foliage, branches, and stems. The standard error of estimate for surface area and biomass ranged from 5 to 10 percent, depending upon the tree components of interest.

594. **Swank, Wayne T.; Swank, W. T. Scott. 1984.** Dynamics of water chemistry in hardwood and pine ecosystems. In: Burt, T. P.; Walling, D. E., eds. Catchment experiments in fluvial geomorphology: Proceedings of a meeting of the International Geographical Union Commission on field experiments in geomorphology; 1981 August 16-24; Exeter and Huddersfield, UK. Norwich, UK: Geo Books: 335-346.

This paper summarizes the alteration of water chemistry during its passage through different ecosystem compartments for three forest types in the Southern Appalachians. There is a significant depletion of hydrogen ions in pine and oak-hickory forests as water passes through successive canopy, forest floor, and soil compartments. The net change in H^+ concentrations between precipitation and stream water is equivalent to about 2 pH units; i.e., pH increases from 4.5 to 6.5. Patterns of base cation changes through compartments are generally similar for the two pine and the hardwood forest types, but with a few exceptions. Patterns between forests appear to be most different for NO_3 and SO_4, which are mediated by microbial transformations.

595. **Swank, Wayne T.; Van Lear, David H. 1992.** Multiple-use management: ecosystem perspectives of multiple-use management. Ecological Applications. 2(3): 219-220.

Preface to a 56-page special emphasis collection of 5 papers on forest management.

596. **Swank, Wayne T.; Vose, James M. 1988.** Effects of cutting practices on microenvironment in relation to hardwood regeneration. In: Smith, H. Clay; Perkey, Arlyn W.; Kidd, William E., Jr., eds. Guidelines for regenerating Appalachian hardwood stands: Proceedings of a workshop; 1988 May 24-26; Morgantown, WV. SAF Publ. 88-03. Morgantown, WV: West Virginia University Books, Office of Publications: 71-88.

Regeneration cutting results in significant changes in the microenvironment of the forest floor and soil. For example, light intensity, surface soil temperature, and soil moisture increase with removal of the forest canopy. These changes influence regeneration success directly through their impact on photosynthesis, heat and frost damage, and available soil moisture. Changes in the microenvironment also influence available nutrients because decomposition and nutrient cycling processes are strongly regulated by soil temperature and moisture. Nutrient availability is further influenced by changes in dry deposition and leaching through the logging slash. The degree of changes in the physical, chemical, and biological properties of the forest floor and soil is dependent upon cutting intensity.

597. **Swank, Wayne T.; Vose, James M. 1990/91.** Watershed-scale responses to ozone events in a *Pinus strobus* L. plantation. Water, Air, and Soil Pollution. 54: 119-133.

High O_3 levels during the 1984 growing season in the Southern Appalachian Mountains caused extensive damage to a 28-year-old white pine plantation on a 13.4-ha watershed at the Coweeta Hydrologic Laboratory. Ozone stress effects included premature senescence and loss of foliage, stimulation of pine seedling germination, reduced basal area increment, and small but measurable increases in NO_3-N and K^+ concentrations in stream water. There were no observable effects of O_3 damage on nutrient concentrations of stemwood and foliage but net nutrient accumulation was reduced due to lower stemwood production. Ozone injury did not predispose trees to root pathogens or bark beetle infestations.

598. **Swift, L. W., Jr. 1984.** Gravel and grass surfacing reduces soil loss from mountain roads. Forest Science. 30: 657-670.

Soil loss from forest roads was measured in the Southern Appalachian Mountains. Losses from a roadbed without surfacing (bare soil) and later with grass cover were compared with those from roadbeds surfaced with different types and amounts of rock. In the first 2 months after construction in a deep sandy loam saprolite, soil loss rates were eight times greater from bare soil than from roadbeds with 15 to 20 cm of gravel. Loss rates declined in a 6-month period of light traffic and rose as logging traffic began. At the conclusion of the timber sale, roads

were reshaped and ungraveled portions grassed. In the third year, erosion rates on the lightly graveled site approximately equaled those of bare soil, twice that of a grassed roadbed. Differences persisted into the fourth year. Maintenance of forest roads disturbed stabilized road surfaces and contributed to soil losses.

599. **Swift, L. W., Jr. 1988.** Forest access roads: design, maintenance, and soil loss. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 313-324.

The construction of forest roads and resulting soil loss have been a continuing area of research and demonstration since Coweeta was established. The low-cost, low-maintenance, intermittent-use road pioneered there is accepted by government and industry land managers and strongly recommended by State agencies. Road sediment is the principal nonpoint source of pollution from forestry activities. Guidelines are given for an inexpensive design and field layout procedure that can produce a serviceable and environmentally acceptable road.

600. **Swift, L. W., Jr.; Blood, Elizabeth R. 1987.** Drought impact research at two LTER sites. In: Southeastern drought symposium Proceedings; 1987 March 4-5; Columbia, SC. South Carolina State Climatology Office Publ. G-30. Columbia, SC: South Carolina Water Resources Commission: 102-105.

The Long Term Ecological Research sites at Coweeta and North Inlet were influenced by the Southeast drought of 1984-86 with total rainfall for 8 consecutive months being less than 50 percent of normal. Between August 1984 and September 1986 only six monthly precipitation totals were at or above 52-year averages at Coweeta. Only seven monthly totals were above the mean at Hobcaw. Low soil-moisture levels were reflected in streamflow; record minimums for low flows were set for 6 consecutive months at Coweeta.

601. **Swift, L. W., Jr.; Cunningham, G. B. 1986.** Routines for collecting and summarizing hydrometeorological data at Coweeta Hydrologic Laboratory. In: Michener, William K., ed. Research data management in the ecological sciences; 1984 November 4-6; Hobcaw Barony, Georgetown, SC. Columbia, SC: University of South Carolina Press: 301-320.

Continuous records of streamflow, precipitation, and other meteorological variables began at Coweeta in 1934. Since that time, data collection, processing, and archiving have changed from tedious manual techniques to computerized methods that have significantly increased accuracy and availability of information. Methods developed at Coweeta have been adopted and applied by national and international research groups. This paper reviews the concepts and procedures developed to collect, edit, and summarize hydrometeorological data at Coweeta and is intended as a reference for users of these data.

602. **Swift, L. W., Jr.; Cunningham, G. B.; Douglass, J. E. 1988.** Climatology and hydrology. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 35-55.

Streamflow from an undisturbed forested watershed is the net result of the physiography of the catchment and its climate. In early reports on the research in the southern Appalachian Mountains, Hursh championed studies to describe and develop understanding of climate, precipitation, soils, and topography of these mountains and how they interact with forest vegetation to produce streamflow. The state of knowledge of climate and streamflow in the Coweeta Basin and understanding of interactions with topography and vegetation are subjects of this chapter.

603. **Swift, Lloyd W., Jr. 1976.** Algorithm for solar radiation on mountain slopes. Water Resources Research. 12: 108-112.

A generalized algorithm provides the daily total of potential solar radiation on any sloping surface at any latitude. The algorithm can be coded as subroutines of a computer model that requires solar radiation as a variable. The required inputs are Julian dates and the latitude, inclination, and aspect of the slope. In addition to computing potential solar radiation, the routine provides estimates of actual radiation on any slope on the basis of measured solar radiation for a nearby horizontal surface that has the same cloud cover.

604. **Swift, Lloyd W., Jr. 1980.** Visitor's guide–Coweeta Hydrologic Laboratory. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

This illustrated folder, prepared for nontechnical visitors to the Laboratory, describes the objectives of watershed management research at Coweeta and gives highlights of results and directions to nine points of interest.

605. **Swift, Lloyd W., Jr. 1983.** Duration of stream temperature increases following forest cutting in the Southern Appalachian Mountains. In: Johnson, A. Ivan; Clark, Robert A., eds. Proceedings of the international symposium on hydrometeorology; 1982 June 13-17; Denver, CO. Bethesda, MD: American Water Resource Association: 273-275.

Cutting timber along small streams in the Southern Appalachian Mountains increases water temperature. Clearcutting all vegetation over 2.5 cm in d.b.h. from a 59.6-ha south-facing watershed in western North Carolina allowed both the magnitude and duration of water temperature increases to be studied. About 958 m^2 of stream were exposed. Daily maximum temperatures at the downstream margin of the cutting were increased an average of 3.3 °C the first two summers after cutting. The increases declined in the next three summers to 1.2 °C. Daily minimums were increased about 1.3 °C both winter and summer, but only in the first year. The daily range

of water temperatures (maximum minus minimum) was increased during all five summers. A method for predicting water temperature changes was tested and found to overestimate the summer increases.

606. **Swift, Lloyd W., Jr. 1983.** Green sponge. The American Tree Farmer. 2(5): 7.

Water yield should be a concern to the tree farmer. Choices in managing Piedmont lands between pine or hardwood forests affect future streamflow amounts. As an example, average streamflow may be 4 area inches greater under hardwood management. However, the change in streamflow due to thinning and cutting previously unmanaged Piedmont forest is greatest for pine stands.

607. **Swift, Lloyd W., Jr. 1984.** Soil losses from roadbed and cut and fill slopes in the Southern Appalachian Mountains. Southern Journal of Applied Forestry 8: 209-215.

Soil losses were measured on the cut, fill, and roadbed surfaces of a forest road at Coweeta. Before grass was planted or gravel spread, roadbed surfaces had the least loss per unit area and loss was primarily waterborne fine particles. A large part of the soil loss from fill slopes was due to slippage of wet soils in early spring. Surface erosion of fills was negligible because storm water from the roadbed was not spilled across loose soil. The cut slopes eroded most, principally because soils were loosened by diurnal cycles of freezing and thawing in winter. This study shows that inclined surfaces of cut and fill slopes are potential sources of large soil loss but these losses can be mitigated by early establishment of grass cover and by design features to control storm water. Soil loss from roadbeds was greatly reduced by gravel surfacing.

608. **Swift, Lloyd W., Jr. 1985.** Forest road design to minimize erosion in the Southern Appalachians. In: Blackmon, B. G., ed. Proceedings of forestry and water quality: a mid-South symposium; 1985 May 8-9; Little Rock, AR. Monticello, AR: University of Arkansas, Department of Forest Resources: 141-151.

Excessive erosion and low serviceability of roads are continuing problems associated with forest management in the mountains of the Southeastern United States. Road and erosion research at Coweeta Hydrologic Laboratory in western North Carolina dates from roadbank stabilization work in the 1930's. Emphasis has been to develop and demonstrate a low-cost, low-maintenance road design. Results cover such features as: drainage and the broad-based dip, cut-bank design and stabilization, roadbed surfacing, brush barriers and filter strips, culvert sizing, and transportation planning. Application of knowledge gained permits roads to be built and maintained at lower cost while providing practical control of sediment input to streams.

609. **Swift, Lloyd W., Jr. 1986.** Access roads. In: Smith, Andrew R., ed. "Nothing Could Be Finer": a story of soil and water conservation in North Carolina; international meeting of the Soil Conservation Society of America; 1986 August 3-7; Winston-Salem, NC. Raleigh, NC: North Carolina Chapter of the Soil Conservation Society of America: 16-17.

Standards developed at Coweeta for forest access roads are described in this chapter of a special booklet on erosion control practices prepared for distribution at the Soil Conservation meeting.

610. **Swift, Lloyd W., Jr. 1986.** Filter strip widths for forest roads in the Southern Appalachians. Southern Journal of Applied Forestry. 10(1): 27-34.

Filter strip standards currently applied to forest roads in the Southern Appalachian Mountains may specify greater widths than are necessary with prevailing construction practices. Measurements of the distance that sediment traveled downslope below newly constructed roads were less than previously reported. Distances were notably less if natural obstructions existed on the forest floor, brush barriers constructed at the edge of the right-of-way, road fills grass-covered, and roads outsloped and drained by broad-based dips. Discussion of management considerations led to proposed revised guidelines for minimum filter-strip widths for the southern mountains.

611. **Swift, Lloyd W., Jr. 1987.** Coweeta Hydrologic Laboratory, North Carolina. In: Greenland, David, ed. The climates of the Long-Term Ecological Research sites. Occas. Pap. 44. Boulder, CO: University of Colorado, Institute of Arctic and Alpine Research: 28-33.

Thirty years of temperature and precipitation data are summarized from a meteorological station at Coweeta. The laboratory covers two adjacent, east-facing, bowl-shaped valleys in the Nantahala Mountain chain of the Southern Appalachian Mountains. The climate of the Appalachian Mountains is distinguished from that of surrounding lowlands by characteristics of high precipitation, moderate temperatures and sustained evaporation rates. Coweeta's climate is classed as Marine, Humid Temperate, but the lower elevations of the Coweeta Basin, including station CS01, are borderline between Marine and Humid Subtropical. Climatic data in this chapter are collected primarily at station CS01 on the valley floor at elevation 685 m. Data from this station are published monthly by the National Climatic Data Center.

612. **Swift, Lloyd W., Jr.; Baker, Samuel E. 1973.** Lower water temperatures within a streamside buffer strip. Res. Note SE-193. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

The removal of streamside vegetation increases the water temperature in mountain streams. Clearcutting and farming have been found to raise temperatures beyond the tolerance level for trout (68 °F). Within the sale area of a commercial clearcut in the mountains of North Carolina, a narrow buffer strip of uncut trees and shrubs was left beside a stream. Although water temperatures within the

sale area may have exceeded 68 °F, the stream immediately below the sale area was never warmer than 62 °F.

613. **Swift, Lloyd W., Jr.; Elliott, Katherine J.; Ottmar, Roger D.; Vihnanek, Robert E. 1993.** Site preparation burning to improve southern Appalachian pine-hardwood stands: fire characteristics and soil erosion, moisture, and temperature. Canadian Journal of Forest Research. 23: 2242-2254.

Three Southern Appalachian stands with sparse and unproductive pine-hardwood overstories and dense *Kalmia latifolia* L. understories were treated to restore productivity and diversity. An adaptation of the fell-and-burn practice was applied and about one-half of the woody fuels were consumed. A range of fire intensities was observed. Flame temperatures approached 800 ° but the heat pulse into the forest floor only reached 60 °C at a depth of 5 cm. Humus and charred leaf litter remained on most of the surface after burning. Evidence of soil erosion was spotty and related to points of local soil disturbance. No soil left the sites. At the end of the first growing season, 23 percent of the burned surfaces were covered by growing plants and 62 percent by residual forest floor and woody debris. Felling and burning reduced evapotranspiration so that soil in the treated areas remained moister than soil under adjacent uncut stands. Opening the sites increased soil temperatures 2 to 5 °C at a depth of 10 cm during the first 16 months.

614. **Swift, Lloyd W., Jr.; Knoerr, Kenneth R. 1973.** Estimating solar radiation on mountain slopes. Agricultural Meteorology. 12: 329-336.

The amount of solar irradiation on a mountain slope is an important parameter for describing the climatology of a sloping site, but measurements are not easily obtained. Daily totals of solar irradiation can be estimated from the daily total of global solar radiation measured on a horizontal surface at a site near enough to have the same cloud cover as the mountain slope. The adjusting function is a ratio of the value of potential solar irradiation for a slope to that for a horizontal surface. Valid estimates of solar radiation input were obtained for two opposite-facing slopes.

615. **Swift, Lloyd W., Jr.; Messer, James B. 1971.** Forest cuttings raise temperatures of small streams in the Southern Appalachians. Journal of Soil and Water Conservation. 26: 111-116.

Stream temperatures were measured during six forest-cutting treatments imposed on 23- to 70-acre watersheds in the Southern Appalachian Mountains. Where forest trees and all understory vegetation were completely cut, maximum stream temperatures in summer were raised from the normal 66 °F up to 73 °F or more. Some extreme treatments raised temperatures over 12 °F above normal. Where streambank vegetation was uncut or had regrown, summer maximums were unchanged or reduced from levels found under uncut mature hardwoods. Increases in stream temperature were judged to degrade water quality and constitute thermal pollution because, after each clearcut, water temperatures exceeded optimum levels for trout habitat.

616. **Swift, Lloyd W., Jr.; Ragsdale, Harvey L. 1985.** Meteorological data stations at Long-Term Ecological Research sites. In: Hutchison, B. A.; Hicks, B. B., eds; The forest-atmosphere interaction: Proceedings of the forest environment measurements conference; 1983 October 23-28; Oak Ridge, TN. Dordrecht, Holland: D. Reidel Publishing Company: 25-37.

Long-Term Ecological Research (LTER) sites have been designated in 11 ecosystems under the auspices of the National Science Foundation. Meteorological observations are part of the needed baseline data. An early accomplishment of this coordinated research program is a standard for LTER meteorological stations. National goals of the LTER program and the research objectives at each site are related in this report to specific needs for meteorological data that defined the concept and structure of the station standards. Each meteorological station must serve two purposes: support ongoing research at the site and provide climatic data for long-term studies and intersite comparisons. The recommended standard is flexible. It establishes a core level of participation yet allows for considerable variation in data requirements of different ecosystems.

617. **Swift, Lloyd W., Jr.; Schreuder, Hans T. 1981.** Fitting daily precipitation amounts using the Sb distribution. Monthly Weather Review. 109: 2535-2541.

The log-normal, gamma, Weibull, Sb and beta distributions were fit to daily precipitation amounts for each calendar month for a 38-year period. Data are from the high precipitation zone of the southern Appalachian Mountains. The Sb distribution, a generalization of the log-normal, consistently fit the data best. The gamma distribution fit rainfall amounts accumulated for 2 and 3 consecutive wet days. Higher-order Markov chains, up through the fifth order, described the data better than lower-order chains. The Sb distribution of precipitation amounts on all dates preceded by dry days is different from that for all dates preceded by precipitation.

618. **Swift, Lloyd W., Jr.; Swank, Wayne T. 1981.** Long term responses of streamflow following clearcutting and regrowth. Hydrological Sciences Bulletin. 26: 245-256.

Long-term changes in streamflow following forest cutting for three experimental basins show that streamflow declines with the logarithm of time as the forest regrows. The decline is related to vegetation regrowth, but is not a consistent function of simple stand measurements. The mixed hardwood forest of one basin was clearcut twice in 40 years. During the second regrowth period, streamflow increases were about one-half those after the first treatment. Concurrently, two other basins were cut whose mid-elevations are 400 m higher. Both streamflow increases were less than on the lower basin. Similar variability of increases for the three concurrent treatments appears partly related to precipitation.

619. **Swift, Lloyd W., Jr.; Swank, Wayne T.; Mankin, J. B.; Luxmoore, R. J.; Goldstein, R. A. 1975.** Simulation of evapotranspiration and drainage from mature and clear-cut deciduous forests and young pine plantation. Water Resources Research. 11(5): 667-673.

PROSPER, a model for water exchange between soil, plant, and atmosphere, was used to simulate evapotranspiration and annual streamflow for 2 years from a mature oak-hickory forest in the Southern Appalachian Mountains. For a year having unusually high precipitation, simulated streamflow agreed within 1.5 percent with measured streamflow. Additional simulations were made using the same climatic data, but vegetation parameters were modified to represent a regrowing coppice forest after clearcutting, and a young white pine plantation. The predicted changes in streamflow showed good agreement with measured changes determined from watershed experiments at Coweeta Hydrologic Laboratory.

620. **Swift, Lloyd W., Jr.; Waide, Jack B.; White, David L. 1989.** Refinements in the Z-T method of extreme value analysis for small watersheds. In: 6th conference on applied climatology; 1989 March 7-10; Charleston, SC. Boston, MA: American Meteorological Society: 60-65.

The drought of 1984-86 caused record low streamflow at Coweeta including 277 consecutive days when flow on Watershed 8 was in the lowest 10 percent of the 52 years' record. The Zelenhasic and Todorovic method of extreme value analysis was adapted to small watershed flow data yielding a 200-plus year recurrence interval for this event. Additional refinements of the method will be necessary to use the longer term precipitation data to estimate streamflow drought occurences.

621. **Swift, Lloyd W., Jr.; Waide, Jack B.; White, David L. 1990.** Application of the Z-T extreme event analysis using Coweeta streamflow and precipitation data. In: Greenland, David; Swift, Lloyd W., Jr., eds. Climate variability and ecosystem response: Proceedings of a long-term ecological research workshop; 1988 August 21-23; Boulder, CO. Gen. Tech. Rep. SE-65. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 13-18.

A technique for drought or flood analysis, after Zelenhasic and Todorovic, promises to improve the definition of both duration and magnitude of extreme flow events for river-sized basins. The technique has been applied to a smaller basin at the Coweeta Long Term Ecological Research site using both streamflow data and a longer precipitation record. This report illustrates the technique and describes needed adjustments to apply the method to stream-sized basins.

622. **Swindel, Benee F.; Douglass, James E. 1984.** Describing and testing nonlinear treatment effects in paired watershed experiments. Forest Science. 30(2): 305-313.

In forest hydrology research, treatment effects are commonly assumed to be proportional to the hydrologic response measured on a control watershed, and are fitted and tested for significance by linear regression techniques. More likely the treatment effect (measured as the difference between pre- and post-treatment regressions of the treatment basin's response on the control basin's response to weather) is nonlinear, unimodal in midrange, and asymptotically zero in one or both extreme ranges. This paper offers simple models for describing such treatment effects and gives illustrative fitting and testing procedures.

623. **Tan, K. H.; Sihanonth, P.; Todd, R. L. 1978.** Formation of humic acid-like compounds by the ectotrophic mycorrhizal fungus *Pisolithus tinctorius*. Soil Science Society of America Journal. 42: 906-908.

Formation of organic compounds by the ectomycorrhizal fungus, *Pisolithus tinctorius*, was studied to establish the relationship of these microbial products to humic and fulvic acids. The fungus was grown in a Melins-Norkrans liquid culture with either sucrose or a mixture of L-malic and L-succinic acid as the C and energy source. The biologically synthesized substances were characterized by chemical and infrared analyses.

624. **Tate, Cathy M.; Meyer, Judy L. 1983.** The influence of hydrologic conditions and successional state on dissolved organic carbon export from forested watersheds. Ecology. 64: 25-32.

Concentration and export of disolved organic carbon (DOC) were compared in streams draining four watersheds with different treatment histories in 1969-70 and again in 1979-80. In 1969-70, the watersheds were: old field (year 1), hardwood coppice (year 7), white pine (year 13) and mature hardwood (undisturbed for year 45). DOC concentrations were three to four times greater than in 1979-80 on all watersheds. Annual export was greatest from the hardwood and old-field watersheds and least from the pine and coppice during both years. Despite higher runoff during 1979-80, DOC export was less during that year on all watersheds. Although there appears to be a trend toward decreasing DOC concentration and export over the first two decades of secondary succession, differences caused by periodic variations in runoff are far more significant than any successional changes observed.

625. **Taylor, Allan B.; Velbel, Michael Anthony. 1991.** Geochemical mass balances and weathering rates in forested watersheds of the southern Blue Ridge. 2: Effects of botanical uptake terms. Geoderma. 51: 29-50.

Geochemical mass balance methods are commonly used in small-watershed studies to estimate rates of primary-mineral weathering and soil formation, and the contribution of these processes to cation budgets, nutrient cycling, and landscape susceptibility to acid deposition. Many researchers employ the "balance sheet" approach, a system of simultaneous linear equations with constant coefficients that represent the steady-state behavior of the modeled system. Most workers also assume that the steady-state assumption for the entire system means that

there is no net elemental transfer between biomass and inorganic compartments of the system. Weathering rates for seven forested watersheds in the southern Blue Ridge Mountains are calculated twice, allowing for net element exchange with biomass, and assuming no net exchange with biomass. Our calculations show that misunderstanding the mathematical constraints which are built into the most widely used geochemical mass balance equations commonly causes underestimates of up to a factor of 4 in the calculated rates of mineral weathering and soil formation. This problem is most pronounced for minerals containing major nutrient elements.

626. **Taylor, G. E., Jr.; Ross-Todd, B. M.; Allen, E.; Conklin, P.; Edmonds, R.; Joranger, E.; Miller, E.; Ragsdale, L.; Shepard, J.; Silsbee, D.; Swank, W. 1992.** Patterns of tropospheric ozone in forested landscapes of the Integrated Forest Study. In: Johnson, Dale W.; Lindberg, Steven E., eds. Atmospheric deposition and forest nutrient cycling: a synthesis of the Integrated Forest Study. Ecological Studies, vol. 91. New York: Springer-Verlag: 50-71.

This chapter compares the patterns of ozone concentration among the sites of the Integrated Forest Study. This analysis, based on data collected in 1987 and 1988, addresses spatial and temporal patterns among sites rather than site-specific features. The temporal patterns of interest involve diurnal, monthly, seasonal, and annual time scales, whereas the spatial patterns focus on elevation, proximity to precursors, latitude, and regional meteorology conditions. Finally, the analysis compares patterns of ozone concentration across all sites with concurrent data on nitrogen and sulfur deposition.

627. **Taylor, Randolph, W.; Williams, Arthur L., Dashek, William V.; Swank, Wayne T. 1989.** Ultrastructure and amino acid/protein contents of *Pinus strobus* needles: a potential monitor for ozone (O_3). Biodeterioration Research 2: 549-570.

Ambient levels of ozone in the southeastern region are suspected to adversely affect growth of eastern white pine. Proline (pro) can accumulate in plant leaves through environmental stress and may be a potential marker of ozone pollution. Biochemical extraction and quantification of needle soluble pro for white pine at Coweeta indicate that soluble pro is of sufficient magnitude that could prove useful as a bioassay for ozone monitoring. The application of scanning electron microscopy of stomated topography and extraction as an aid to further interpret ozone effects is illustrated.

628. **Tebo, L. B., Jr. 1955.** Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the Southern Appalachians. Progressive Fish-Culturist. 17: 64-70.

Siltation resulting from improper landuse practices is regarded as one of the most important factors contributing to a reduction in the acreage of desirable fishing waters. This report presents quantitative data regarding the effect of siltation on bottom fauna of trout streams in the Southern Appalachians.

629. **Tebo, L. B., Jr.; Hassler, W. W. 1961.** Seasonal abundance of aquatic insects in western North Carolina trout streams. Journal of the Mitchell Society. 77(2): 249-259.

A total of 267 ft^2 samples of invertebrate bottom fauna were collected over 18 months from Shope Fork and Ball Creek. With low standing crops, monthly averages ranged from 19 organisms per ft^2 in February to 93 per ft^2 in September. Peaks in monthly number of organisms came in September and April; the spring counts due to mayflies and fall to caddisflies. Three orders made up 75 percent of total collections: Ephemeroptera, Trichoptera, and Diptera. Coleoptera and Plecoptera filled the remaining 25 percent, with Plecoptera the dominant order in November and December.

630. **Tew, Howard C.; Price, Lane C.; Swift, Lloyd W., Jr. 1985.** The layman's guide to private access road construction in the southern Appalachian Mountains. Waynesville, NC: U.S. Department of Agriculture, Soil Conservation Service. 29 p.

This fully illustrated booklet guides the farmer, home owner, summer home developer, contractor or real estate agent through the planning, design, construction and maintenance stages for a good access road. Standards include the broad-based dip and other options based upon Coweeta forest access road demonstrations.

631. **Todd, R. L.; Cromack, K., Jr.; Knutson, R. M. 1973.** In situ observations of microbial biomass by scanning electron microscopy. In: Rosswall, Thomas, ed. Modern methods in the study of microbial ecology: Proceedings of the symposium; 1972 June 19-23; Uppsala, Sweden. Bull. of the Ecol. Res. Comm., 17. Stockholm, Sweden: National Science Research Council: 109-118.

Improved methods are needed for assessing the role of microflora in decomposition and nutrient cycling. This paper describes an assessment technique that enables microbiologists to examine micro-organisms in situ.

632. **Todd, R. L.; Kerr, T. 1972.** Scanning electron microscopy of microbial cells on membrane filters. Applied Microbiology. 23: 1160-1162.

Scanning electron micrographs of a *Pseudomonas* species, *Staphylococcus aureus*, and *Bacillus subtilis* on two membrane filtration systems are compared.

633. **Todd, R. L.; Meyer, R. D.; Waide, J. B. 1978.** Nitrogen fixation in a Southeastern United States deciduous forest. In: Granhall, U., ed. Environmental role of nitrogen-fixing blue-green algae and asymbiotic bacteria: Proceedings of the 7th international soil zoology colloquium; 1976 September 20-24; Uppsala, Sweden. Ecol. Bull. 26. Stockholm, Sweden: Swedish Soil Science Society: 172-177.

Dinitrogen fixation was quantified in a mixed deciduous forest ecosystem at Coweeta. Rates and annual amounts of nitrogen fixation were measured for several components of a mature oak-hickory forest. Highest rates were observed in the soil (8.53 kg N fixed per ha per year), followed by woody litter (1.66), bole (1.00), leaf litter (0.63), and phyllosphere (0.22). The total amount of nitrogen fixed was estimated as 12.04 kg N per ha per year. Generally these fixation rates for a deciduous forest compare favorably with similar measurements in coniferous forests. These results show that the biological fixation of gaseous nitrogen is a major input of nitrogen to deciduous forest ecosystems.

634. **Todd, R. L.; Nuner, J. H. 1973.** Comparison of two techniques for assessing denitrification in terrestrial ecosystems. In: Rosswall, Thomas, ed. Modern methods in the study of microbial ecology: Proceedings of the symposium; 1972 June 19-23; Uppsala, Sweden. Bull. of the Ecol. Res. Comm. 17. Stockholm, Sweden: National Science Research Council: 277-278.

Gas chromatography is being used to quantify denitrification in a terrestrial ecosystem. These preliminary results compare the rates of denitrification (as determined by the conversion of nitrous oxide to atmospheric nitrogen) to the standard most probable number procedure. While the latter technique can provide only enumeration of denitrifying cells, the gas chromatographic procedure allows for the calculation of actual transfer rates.

635. **Todd, R. L.; Swank, W. T.; Douglass, J. E.; Kerr, P. C.; Brockway, D. L.; Monk, C. D. 1975.** The relationship between nitrate concentration in the Southern Appalachian mountain streams and terrestrial nitrifiers. Agro-Ecosystems. 2: 127-132.

The nitrate content of stream water and the nitrifying bacterial population of the terrestrial horizon were measured in three Southern Appalachian watersheds over a 22-month period. The watersheds studied were a fescue grass catchment, a 15-year-old white pine plantation, and a mature undisturbed hardwood forest. Monthly averages of NO_3-N in stream water from the three watersheds were 730, 190, and 3 ppb respectively; the respective nitrifying populations averaged 16000, 175 and 22 per gram of dry weight for each 40 cm soil profile. These populations were concentrated in the upper 10 cm of the profile (grass = 98 percent, white pine = 90 percent, and hardwood = 88 percent). A correlation is evident between the number of nitrifying bacteria in the soil and the NO_3 content of the streams. Nitrifying activity appears to be dependent on vegetation type and successional stage.

636. **Todd, Robert L.; Cromack, Kermit; Stormer, John C. 1973.** Chemical exploration of microhabitat by electron probe microanalysis of decomposer organisms. Nature 243: 544-546.

A method for chemical analysis of decomposer biomass without destruction of the detrital matrix is discussed. The probe uses a high energy beam of electrons to excite atoms into releasing their particular x-radiation, allowing measurement of essential nutrients for small individual fractions of detritus.

637. **Todd, Robert L.; Sihanonth, Prakitsin; Crossley, D. A., Jr.; Cromack, Kermit, Jr. 1978.** Elemental analysis of terrestrial microflora and fauna using an electron microbeam technique. In: Adrino, D. C.; Brisbin, Lehr, Jr., eds. Environmental chemistry and cycling processes; 1976 April 28 - May 1; Augusta, GA. Symposium Series Conf-760429. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 119-129. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

X-ray microanalysis is a nondestructive, fast, and accurate means of obtaining elemental information about a variety of biologically different samples located within a microhabitat. Combining an x-ray spectrometer and a scanning electron microscope makes it possible for the environmental chemist to visualize the sample and to determine elemental concentration and spatial localization. Elemental concentrations and their distribution can be measured if consideration is given to specimen preparation and proper interpretation of the x-ray data. Analytical procedures (specimen preparation and data interpretation) and the potential of this technique as an environmental research tool are discussed.

638. **Todd, Robert L.; Waide, Jack B.; Cornaby, Barney W. 1975.** Significance of biological nitrogen fixation and denitrification in a deciduous forest ecosystem. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symposium Series Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 729-735. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Gaseous transformations of nitrogen were quantified in relation to other components of the nitrogen cycle of a mixed deciduous forest ecosystem at Coweeta. Rates and total annual amounts of nitrogen fixation and potential denitrification were measured for several components of the litter-soil subsystem of a mature oak-hickory forest. Highest rates of both processes were observed in leaf and woody litter, but highest totals occurred in the soil. Of the total nitrogen input, including that via bulk precipitation, biological fixation accounted for 75 percent. Potential denitrification losses exceeded stream-water losses by 200 times. Results show that consideration must be given to both levels of activity and total fluxes in any examination of the forest nitrogen cycle and that existing pools of nitrogen may not indicate the magnitude of gaseous transformations that are occurring.

639. **Tramer, Elliot J. 1969.** Bird species diversity: components of Shannon's formula. Ecology. 50(5): 927-929.

Shannon's diversity index was calculated for 267 breeding bird censuses. The index was resolved into its components, species richness and relative abundance, to determine which components played a larger role in the determination of diversity patterns. Changes in diversity were correlated closely with species richness, while the relative abundance component remained stable. Photoplankton differ from birds in that the relative abundance component is not stable from one collection to the next. This is attributed to differences in the environmental uncertainty encountered by the two groups. It is suggested that the regulation of diversity by either the species richness or relative abundance components represent alternative strategies which are suited to predictable/nonrigorous and unpredictable/rigorous environments, respectively. Therefore, differences similar to those observed between birds and phytoplankton might be expected in other groups of organisms.

640. **Troendle, Charles A. 1979.** Hydrologic impacts of silvicultural activities. Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers. 105 (IR 1): 57-70.

Hydrologic models can be used to develop a handbook for evaluating impact of silvicultural practices on the hydrologic cycle. Models were evaluated for usefulness in developing regional response relationships and site specific modifiers useful to planners. Empirical relationships which allow pre- and post-treatment evaluation of hydrologic responses were derived from simulations. Prior work on the PROSPER model and Coweeta's Watershed 28 were used in development and illustration of methodology.

641. **Tucker, Larry W. 1984.** Waters of Coweeta. Cullowhee, NC: Western Carolina University; slide-tape program. 5 p.

Script for visitor program that describes Coweeta research accomplishments, prepared for the Laboratory's 50th anniversary celebration.

642. **U.S. Department of Agriculture, Forest Service. 1953.** Waters of Coweeta. Agric. Inf. Bull. 117. Washington, DC: U.S. Department of Agriculture, Forest Service. 22 p.

The results of 20 years of streamflow studies at Coweeta are highlighted. Text and pictorial illustrations are borrowed from a documentary film with the same title.

643. **Ursic, Stanley J.; Douglass, James E. 1979.** The effects of forestry practices on water resources. In: Proceedings of the W. Kelly Mosley environmental forum; 1978 May; Auburn, AL. Auburn, AL: Auburn University Press: 33-49.

This review discusses the effects of management of southern forests on: annual water yield, monthly and seasonal distribution of yield, storm runoff, sediment yield, and water quality.

644. **Van Lear, D. H.; Douglass, J. E. 1982.** Water in the loblolly pine ecosystem - Eastern region. In: Symposium on the loblolly pine ecosystems (East region); 1982 December 8-10; Raleigh, NC. Raleigh, NC: School of Forest Resources: 285-296.

The hydrologic cycle in the loblolly pine ecosystem east of the Mississippi River is discussed with special reference to the effects of silvicultural practices and species conversion on quality and quantity of water yield, storm, runoff, and erosion. The conclusion reached is that adverse impacts of forestry activities can be minimized through careful planning and supervision of operations.

645. **Van Lear, D. H.; Douglass, J. E.; Cox, S. K.; Augspurger, M. K. 1985.** Sediment and nutrient export in runoff from burned and harvested pine watersheds in the South Carolina Piedmont. Journal of Environmental Quality. 14(2): 169-174.

Soil and nutrient export in ephemeral flow were studied over a 3-year period which included clearcutting three loblolly-pine-covered watersheds (0.60 to 1.24 ha). Two preharvest, low-intensity prescribed fires had no effect on flow or water quality. Harvesting after a third fire significantly increased sediment concentration and export, but increases were minor compared with sediment export reported for mechanical site preparation. Nutrient concentrations varied but were generally unaffected by harvest. Because harvest increased runoff, nutrient export was generally increased. Results show that loblolly pine stands in the erosive Piedmont physiographic region can be harvested following a series of low-intensity prescribed fires with minimal soil loss or degradation of water quality.

646. **Van Lear, D. H.; Douglass, J. E.; Cox, S. K.; Augspurger, M. K.; Nodine, S. K. 1983.** Regeneration of loblolly pine plantations in the Piedmont by clearcutting with seed in place. In: Jones, Earle P., Jr., ed. Proceedings of the 2d biennial southern silvicultural research conference; 1982 November 2-4; Atlanta, GA. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 87-93.

Near-maturity plantations of loblolly pine in the Piedmont of South Carolina were successfully regenerated by clear cutting with seed in place. Three prescribed fires prepared the seedbed and adequately controlled hardwood competetion. Two growing seasons after harvest, average seedling density was 21160 stems per acre. An economic comparison of natural and artificial regeneration, plus the success using natural regeneration demonstrates that clearcutting with seed in place is a viable low-cost alternative for regenerating pine plantations.

647. **Van Lear, D. H.; Swank, W. T.; Douglass, J. E.; Waide, J. B. 1983.** Forest management practices and the nutrient status of a loblolly pine plantation. In: Ballard, Russell; Gessel, Stanley P., eds. IUFRO Symposium on forest site and continuous productivity; 1982 August 22-28; Seattle, WA. Gen. Tech. Rep. PNW-163. Portland, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 252-258.

Nutrient budgets for N, P, K, and Ca over a 41-year rotation were estimated for two *Pinus taeda* watersheds on poor sites in the upper Piedmont of South Carolina. Whole-tree harvesting of above-stump biomass removed more than twice the N and P, and almost twice the K and Ca, as conventional harvest of boles only. Nutrient outputs exceeded inputs for P, K, and Ca on even the conventionally harvested watershed. Harvesting and/or prescribed burning were the major causes of N and P loss from both watersheds, and stormflow and leaching were major sources of cation loss. Precipitation and N fixation were major sources of nutrient input to the ecosystems. Findings suggest that harvest of boles only on rotations of moderate length and leaving the forest floor and logging slash in place will help minimize adverse effects of clearcutting on the nutrient status, and thus the productivity, of these sites.

648. **Van Lear, D. H.; Taras, M. A.; Waide, J. B.; Augspurger, M. K. 1986.** Comparison of biomass equations for planted vs. natural loblolly pine stands of sawtimber size. Forest Ecology and Management. 14: 205-210.

Equations predicting biomass of components of sawtimber-size trees in a near-maturity loblolly pine plantation were compared to similar equations for an uneven-aged natural loblolly pine stand. Combined analysis of the two sites revealed that curves estimating total tree, stem wood, stem bark, branches, and foliage plus branches weights were significantly different, while curves predicting biomass for total stem and foliage were similar. Biomass equations differ because of variations in tree component ratios and taper associated with site and stand conditions.

649. **Van Lear, David H.; Kapeluck, Peter R.; Waide, Jack B. 1990.** Nitrogen pools and processes during natural regeneration of loblolly pine. In: Gessel, S. P.; Lacate, D. S.; Weetman, G. F.; Powers, R. F., eds. Sustained productivity of forest soils: Proceedings of the 7th North American forest soils conference; 1988 July 24-28; Vancouver, BC. Vancouver, BC: Forestry Publications, University of British Columbia: 234-252.

Nitrogen pools in a mature loblolly pine (*Pinus taeda* L.) plantation were determined and changes in nitrogen storage and fluxes following forest harvest were evaluated. Over 80 percent of the stored nitrogen on this xeric Piedmont site was in organic fractions of the mineral soil, while <10 percent each was in forest floor and stand biomass components. Conventional harvest removed half of the above-stump pine biomass, leaving the remainder to act as a minor nitrogen sink and slow-release fertilizer. Harvest increased net mineralization and nitrification in the mineral soil; but nitrogen immobilization by soil organisms and uptake by regrowth, along with delayed nitrification, minimized nitrogen losses from the ecosystem.

650. **Van Lear, David H.; Waide, Jack B.; Teuke, Michael J. 1984.** Biomass and nutrient content of a 41-year-old loblolly pine (*Pinus taeda* L.) plantation on a poor site in South Carolina. Forest Science. 30(2): 395-404.

Biomass and nutrient content regression equations were developed from analysis of 16 loblolly pine trees growing in a 41-year-old plantation on a site in the upper Piedmont of South Carolina. Nutrient concentrations were highest in foliage and lowest in wood. Predictions of stand nutrient content were similar regardless of whether estimated by regression equations relating nutrient content of tree components to d.b.h. or by multiplying predicted total biomass of each component by its average weighted nutrient concentration. Nutrient contents of other nearly mature loblolly pine plantations could be estimated by determining average weighted nutrient concentrations of biomass components by sampling a small number of trees and multiplying these values by stand dry weight as predicted from presented biomass equations.

651. **Van Miegroet, Helga. 1990.** Forest hydrology and ecology at Coweeta. Environmental Management. 14(2): 284-285.

A review of the Coweeta Symposium volume.

652. **Velbel, M. A. 1988.** Weathering and soil-forming processes. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 93-102.

Weathering of rocks and minerals is one of the most important processes operating at the surface of the earth. Most weathering profiles of the Coweeta Hydrologic Laboratory comprise thin A and B horizons atop substantial thicknesses of saprolite. Rock weathering to saprolite occurs primarily via weathering of three major rock-forming minerals: biotite mica, almandine garnet, and plagioclase feldspar. Geochemical mass-balance calculations permit quantification of mineral weathering rates and rates of geomorphically significant saprolitization. Transformation of bedrock to saprolite prepares the landscape for erosion at a rate equal to the long-term average denudation rate for the Southern Appalachians (4 cm/1000 yrs), suggesting that dynamic equilibrium of the landscape prevails in the longterm. In the (geologically) shortterm, erosion at the top of the profile is much more sporadic.

653. **Velbel, M. A. 1993.** Weathering and pedogenesis at the watershed scale: some recent lessons from studies of acid-deposition effects. Chemical Geology. 107: 337-339.

Geochemical mass balance is commonly used to calculate mineral weathering rates. Such studies invariably find higher present-day rates and generally conclude that the higher rates are a consequence of recent environmental acidification. However, because the residual solids which are the basis of the long-term estimate are time-integrated accumulations of weathering products, it may be inappropriate to compare short-term rates from solute input-output budgets with long-term rates from bulk profile chemistry. There are disparities in both the time scales over which the two methods "measure" rates, and

the volume fraction of the regolith being sampled. Soils better integrate time; solute budgets better integrate space.

654. **Velbel, Michael Anthony. 1984.** Natural weathering mechanisms of almandine garnet. Geology. 12: 631-634.

The mechanism, and rate-limiting step, of almandine garnet weathering is apparently strongly dependent on the chemical environment in which weathering occurs. Weathering of almandine garnet in the oxidized, vadose zone of saprolite begins at grain boundaries and along fractures traversing the garnet grains. Large, well-defined etch pits are absent on the underlying garnet surface. Thus, diffusion (transport) of reactants and/or products through a gibbsite-goethite layer is the rate-limiting step in the weathering of almandine garnet in the oxidizing environment of the saprolite. In soils, garnet surfaces are directly exposed to weathering solutions without the intervening layer. Such "unprotected" grains in soils (and stream sediments) exhibit numerous large, well-developed etch pits. Surface-reaction control, rather than transport control, prevails. Biochemical or biological processes in the soil apparently prevent the gibbsite-goethite layer from forming or persisting.

655. **Velbel, Michael Anthony. 1985.** Geochemical mass balances and weathering rates in forested watersheds of the southern Blue Ridge. American Journal of Science. 285: 904-930.

Weathering rates of rock-forming silicate minerals in natural forested watersheds can be calculated using a system of geochemical mass balance equations constructed and constrained by petrologic, mineralogic, hydrologic, botanical, and aqueous geochemical data. Solving the systems of equations for the weathering rates of biotite mica, almandine garnet, and oligoclase-andesine plagioclase feldspar in deeply weathered schists and gneisses of Coweeta suggests that: (1) the rate at which the weathering front penetrates into the fresh rock agrees well with the "average" denudation rate for the Southern Appalachians, (2) rates of garnet and plagioclase weathering are one to two orders of magnitude slower than rates determined in laboratory experiments, (3) rates of mineral weathering and formation at Coweeta appear sufficient to neutralize atmospheric hydrogen ion input. The relatively good accord between field and laboratory results suggests that sources of error may be small and that mass-balance models provide estimates of rates of important environmental processes.

656. **Velbel, Michael Anthony. 1985.** Hydrogeochemical constraints on mass balances in forested watersheds of the Southern Appalachians. The Chemistry of Weathering: 231-247.

Two variables, parent-rock type and flushing rate (the amount of water flushed through the weathering profile per hectare per year), control the long-term average dissolved load of streams in forested watersheds of southwestern North Carolina. The same variables explain qualitative stability relations, as shown by stability field diagrams that are, in turn, consistent with the hydrology and kaolinite-gibbsite clay mineralogy of the profiles. Tardy's Re, a simple semiquantitative mass-balance tool, ranges from 1.36 to 1.65, again qualitatively consistent with the known clay mineralogy of the systems. The consistency of hydrology, aqueous geochemistry and clay mineralogy places useful constraints on more sophisticated geochemical mass-balanced models.

657. **Velbel, Michael A. 1987.** Alluvial fan origin for terrace deposits of the southeast PreNational Technical Information Services Quadrangle, near Otto, North Carolina. Southeastern Geology. 28(2): 87-103.

Lithologies and structures in unconsolidated terrace gravels, sands, and silts near Otto, NC suggest deposition on an alluvial fan. Deposits included laterally extensive sheets of massive, poorly sorted, matrix-supported conglomerate interbedded with channel-filling cross-bedded sands, and tabular sheets of homogenous or poorly plane-laminated fine sands and silts. One prominent fine-sand interval exhibited a red oxidized lower portion grading upward into a white horizon. The white interval had a distinctive vertical prismatic structure strongly reminiscent of natric or salic horizons of arid alluvial soils. These deposits are interpreted as debris flow, alluvial channel, and overbank deposits (with some arid paleosol development) on local alluvial fans. The record of episodic sedimentation and climate change is consistent with recent sedimentological, geomorphic, and paleoclimatological studies, suggesting that climate may vary significantly on time scales approaching the mean recurrence interval of sedimentation episodes on the fan.

658. **Velbel, Michael Anthony. 1989.** Discussion of "Rates of soil formation: implications for soil-loss tolerance," by E. B. Alexander. Soil Science. 148(1): 71-74.

Soil formation rates reported by Alexander may be low by a factor of 2 to 3 because the biological uptake and storage in forest biomass of minerals released by weathering reactions are omitted from his calculation.

659. **Velbel, Michael Anthony. 1989.** Effect of chemical affinity on feldspar hydrolysis rates in two natural weathering systems. Chemical Geology. 78: 245-253.

Studies of alkali-feldspar hydrolysis kinetics show that weathering rates in natural systems are up to three orders of magnitude slower than laboratory rates. The hypothesis is rejected that decelerated natural-system rates result from lower thermodynamic affinities for the hydrolysis reaction in natural systems than in laboratory systems. The chemical affinities for the feldspar hydrolysis reaction in two well-constrained natural systems are significantly higher than the threshold value at which affinity would exert detectable influences on the reaction rates. Differences in feldspar weathering rates between natural and laboratory systems are most likely due to a combination of experimental preparation artifacts, loss of reactive surface to the formation of etch pits in naturally weathered feldspars, and inhomogeneous access of reactive fluids to those surfaces.

660. **Velbel, Michael Anthony. 1989.** Weathering of hornblende to ferruginous products by a dissolution-reprecipitation mechanism: petrography and stoichiometry. Clays and Clay Minerals. 37(6): 515-524.

Hornblende of the Carrol Knob mafic complex, weathered under humid, temperate conditions has a dissolution-reprecipitation reaction in which hornblende dissolved stoichiometrically and the ferruginous and aluminous weathering products (goethite, gibbsite, and kaolinite) precipitated from solution. During the earliest state of alteration, ferruginous weathering products formed as linings of fractures within and around crystals and cleavage fragments of hornblende. Coalescence of etch pits during more advanced weathering produced denticulated terminations on hornblende remnants in dissolution cavities bounded by ferruginous boxworks. Dissolution cavities are devoid of weathering products. Only Al and Fe were conserved over microscopic distances; alkali and alkaline-earth elements were stoichiometrically removed from the weathering microenvironment during the weathering process.

661. **Velbel, Michael Anthony. 1990.** Influence of temperature and mineral surface characteristics on feldspar weathering rates in natural and artificial systems: a first approximation. Water Resources Research. 26(12): 3049-3053.

Rates of alkali-feldspar hydrolysis in near-neutral pH range are three orders of magnitude slower in natural systems than in laboratory experiments. Correcting for differences in temperature between natural weathering and laboratory systems reduces the disparity by a factor of 5. Any remaining disparity can be accounted for by differences in effective surface area and total surface area; the ratio of effective-to-total surface area in natural systems is generally considerably smaller. This may be due to experimental preparation and to the fact that naturally weathered feldspars have lost much of their most reactive surface to the formation of etch pits. Hydrological factors such as inhomogeneous access of percolating fluids to mineral surfaces may also reduce the proportion of mineral surface area reacting in natural systems.

662. **Velbel, Michael Anthony. 1992.** Geochemical mass balances and weathering rates in forested watersheds of the southern Blue Ridge. 3: Cation budgets and the weathering rate of amphibole. American Journal of Science 292: 58-78.

The geochemical mass balance of alkali and alkaline-earth elements in a southern Blue Ridge watershed underlain by amphibolite (Carroll Knob Complex on Watershed 3 of Coweeta Hydrologic Laboratory), can be explained by weathering of plagioclase (oligoclase-andesine), hornblende (ferroan pargasite), biotite, and calcite, and elemental uptake by forest biota. Feldspar and biotite weathering rates are similar to previously calculated rates for similar minerals in the surrounding gneissic/schistose watersheds. However, the similarity of feldspar weathering rates despite significant differences in modal abundance suggests that feldspar in the Carroll Knob Complex is somewhat less reactive than is plagioclase in the surrounding rocks. Hornblende and plagioclase weathering rates in Coweeta Watershed 3 are approximately equal, consistent with experimentally determined rates and empirical weathering series.

663. **Velbel, Michael Anthony. 1993.** Constancy of silicate-mineral weathering-rate ratios between natural and experimental weathering: implications for hydrologic control of differences in absolute rates. Chemical Geology. 105: 89-99.

Inverse models that apportion watershed geochemical mass balance over estimated mineral surface area give weathering rates for individual silicate minerals one to three orders of magnitude slower than laboratory rates. The coefficient that corrects the weathering rate for any mineral from a laboratory data-set to a field setting is identical to the corresponding coefficient for any other mineral in the same data sets. Physical (e.g., hydrologic) controls, rather than compositional or chemical controls, cause the difference between weathering rates in nature and the laboratory. Because flow in natural weathering profiles is spatially heterogeneous, not all of the potentially available surface in natural systems actually participates in reactions with pore fluids.

664. **Velbel, Michael Anthony. 1993.** Formation of protective surface layers during silicate-mineral weathering under well-leached, oxidizing conditions. American Mineralogist. 78: 405-414.

Formation of a protective surface layer of products through which aqueous reactants or products must diffuse during silicate-mineral weathering requires that (1) elements remain immobile, and (2) the volume of product is greater than volume of reactant. Minerals involving most major rock-forming silicates (feldspars, pyroxenes, amphiboles, and olivines) weathering to common oxides and 1:1 clays are characterized by the volume of product which is less than that of the reactant. Protective surface layers cannot form on these minerals; instead etch pits and porous pseudomorphs are formed by interface-controlled reactions. However, reactant-product mineral suites involving almandine and spessartine garnets are characterized by the volume of product, which is greater than that of reactant. These weathered garnets commonly exhibit laterally continuous, nonporous surface layers underlain by smooth, rounded reactant-mineral surfaces. The rate-determining step during weathering in these instances is diffusion through the surface layer of weathering products.

665. **Velbel, Michael Anthony. 1993.** Temperature dependence of silicate weathering in nature: how strong a negative feedback on long-term accumulation of atmospheric CO_2 and global greenhouse warming? Geology 21: 1059-1062.

Estimation of the temperature dependence of natural feldspar weathering in two catchments at different elevations yields an apparent Arrhenius activation energy of 18.4 kcal/mol, much higher than most laboratory values. This finding supports recent suggestions that

hydrolytic weathering of silicate minerals may consume carbonic acid and thereby remove atmospheric carbon dioxide more rapidly with increasing temperature than previously thought. This result provides a stronger negative feedback on longterm greenhouse warming than has been assumed in most models of global carbon cycling. The present estimate was determined from the ratio of feldspar weathering rates (determined by geochemical mass balance) in the southern Blue Ridge Mountains of North Carolina. Temperature (a function of elevation) is the only factor that differs between the two catchments; parent rock type, aspect, hillslope hydrology, and vegetation type and successional stage are the same in both.

666. **Vimmerstedt, John P. 1959.** Site index curves for Southern Appalachian white pine plantations. Res. Notes 131. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 2 p.

Site quality is a determining factor in how well white pine will grow in the Southern Appalachians. Site index curves are a convenient indicator of site quality. This paper gives site index curves for the Southern Appalachians that can be used to predict tree growth.

667. **Vispo, C. R. 1988.** An observation of a wild group of Masked Shrews, *Sorex cinereus*. The Canadian Field-Naturalist. 102(4): 731-733.

A group of masked shrews, *Sorex cinereus*, were active together in a mountain forest in Macon County, western North Carolina. A literature review of similar observations and the results of stomach analysis led to the conclusion that a concentration of prey during a dry spring may have caused the aggregation found.

668. **Vitousek, Peter M.; Gosz, James R.; Grier, Charles C.; Melillo, Jerry M.; Reiners, William A.; Todd, Robert L. 1979.** Nitrate losses from disturbed ecosystems. Science. 204: 469-474.

A systematic examination of nitrogen cycling in disturbed forest ecosystems demonstrates that eight processes, operating at three stages in the nitrogen cycle, could delay or prevent solution losses of nitrate from disturbed forests. An experimental and comparative study of nitrate losses from trenched plots in 19 forest sites throughout the United States suggests that four of these processes (nitrogen uptake by regrowing vegetation, nitrogen immobilization, lags in nitrification, and a lack of water for nitrate transport) are the most important. The net effect of all of these processes except uptake by regrowing vegetation is insufficient to prevent or delay losses from relatively fertile sites, and hence such sites have the potential for very high nitrate losses following disturbance.

669. **Vose, J. M.; Swank, W. T. 1992.** Water balances. In: Johnson, Dale W.; Lindberg, Steven E., eds. Atmospheric deposition and forest nutrient cycling: a synthesis of the Integrated Forest Study. Ecological Studies, vol. 91. New York: Springer-Verlag: 27-49.

The hydrologic simulation model PROSPER was used to determine site water balances at eight IFS study sites. These data were then coupled with nutrient concentration data from lysimeters to determine nutrient outputs. Site specific climatic, vegetation, and soils data were used in the simulations. Examination of evapotranspiration (ET) and outflow components of PROSPER indicated reasonable model performance. ET estimates ranged from 33 to 105 cm/yr across the eight forested sites. On gauged watersheds, there was generally good agreement between measured and predicted water and nutrient fluxes.

670. **Vose, James M.; Swank, Wayne T. 1990.** Assessing seasonal leaf area dynamics and vertical leaf area distribution in eastern white pine (*Pinus strobus* L.) with a portable light meter. Tree Physiology. 7: 125-134.

A portable light meter was evaluated to quantify seasonal photosynthetically active radiation (PAR) interceptions, projected stand leaf area index (LAI), and vertical LAI distribution in a 32-year-old eastern white pine (*Pinus strobus* L.) plantation. Canopy PAR transmittance measured with the ceptometer was converted to LAI with the Beer-Lambert equation. The ceptometer was sensitive to changes in PAR transmittance resulting from foliage growth. Predicted stand LAI ranged from 3.5 in the dormant season to a maximum of 5.3 in late July. Predicted LAI values were within 9 percent of values determined from destructive sampling. The ceptometer was also sensitive to seasonal changes in PAR transmittance within the canopy.

671. **Vose, James M.; Swank, Wayne T. 1990.** A conceptual model of forest growth emphasizing stand leaf area. In: Dixon, R.; Meldahl, R.; Ruark, G.; Nussen, N., eds. Forest growth: process modeling of responses to environmental stress. Portland, OR: Timber Press: 278-287.

A conceptual model of forest stand growth based on radiation interception, conversion efficiency, respiration costs, and carbon allocation patterns is developed. A critical model component is leaf area index (LAI), which influences the amount of radiation interception, an important determinant of forest growth. Changes in resource availability (water, nutrients) influence the amount and vertical distribution of stand radiation interception. Conversion efficiency is modeled as a function of environmental conditions (photon flux density, water, nutrients, temperature). Little is known about the effects of resource supply on respiration, an important process influencing the availability of fixed carbon for stemwood growth. Carbon allocation is also partially regulated by stand environmental conditions (e.g., more carbon is allocated belowground on dry and infertile sites). The proposed modeling approach has practical utility in that it can be easily understood, parameterized, and tested.

672. **Vose, James M.; Swank, Wayne T. 1990.** Preliminary estimates of foliar absorption of ^{15}N-labeled nitric acid vapor (HNO_3) by mature eastern white pine

(*Pinus strobus*). Canadian Journal of Forest Resources. 20: 857-860.

We used a direct approach to quantify foliar N absorption by exposing foliage of mature eastern white pine (*Pinus strobus* L.) to ^{15}N-labeled nitric acid vapor (HNO_3). Foliage on terminal portions of branches in a 31-year-old white pine plantation was enclosed in 9.0-L teflon film branch cuvettes and exposed to 10, 50, and 100 ppb $H^{15}NO_3$ for 12 to 30 hours. Foliar absorption rates ranged from 0.026 μg $^{15}N/g/h$ at 10 ppb to 0.267 μg $^{15}N/g/h$ at 100 ppb. Extrapolation to the entire canopy resulted in an estimated absorption of 0.30 to 0.50 kg N/ha/yr at ambient HNO_3 concentrations. In contrast, canopy input-output estimates for the same forest stand indicated a depletion of 2.3 kg N/ha/yr by the forest canopy.

673. **Vose, James M.; Swank, Wayne T. 1991.** A soil temperature model for closed canopied forest stands. Res. Pap. SE-281. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 11 p.

A microcomputer-based soil temperature model was developed to predict temperature at the litter-soil interface and soil temperatures at three depths (0.10, 0.20, and 1.25 m) under closed forest canopies. Comparisons of predicted and measured soil temperatures indicated good model performance under most conditions. When generalized parameters describing soil thermal characteristics were used, predicted values were generally within 1 to 3 °C of measured values.

674. **Vose, James M.; Swank, Wayne T. 1993.** Site preparation burning to improve southern Appalachian pine-hardwood stands: aboveground biomass, forest floor mass, and nitrogen and carbon pools. Canadian Journal of Forest Research. 23: 2255-2262.

On three sites in the Southern Appalachians, stands characterized by sparse overstories and dense *Kalmia latifolia* shrub layers were felled in early summer and burned in early fall. Amounts of aboveground vegetation and forest floor mass, nitrogen (N), and carbon (C) were measured before and after treatment by sampling wood, foliage, herbs and grasses, and forest floor. Burning decreased woody mass by 48 to 60 percent across the three sites. Significant losses of mass, N, and C occurred in the loose litter layer of the forest floor, but not in the humus layer. Total aboveground N losses across sites ranged from 193 to 480 kg/ha. These losses may be significant because N availability is low on these sites. Variations in patterns of mass, N, and C consumption were related to differences in amounts, types, size distributions, and moisture contents of fuels.

675. **Vose, James M.; Swank, Wayne T. 1994.** Effects of long-term drought on the hydrology and growth of a white pine plantation in the southern Appalachians. Forest Ecology and Management. 64(1): 25-39.

The Southern Appalachians experienced record precipitation deficits for 4 consecutive years in the mid-1980's. The impacts of the drought on the hydrology and stemwood growth of a 33-year-old white pine plantation were analyzed. Increment cores and dendrometer bands indicated a significant reduction in basal area growth during the drought for all tree classes and shifts in patterns of seasonal growth. There was little variation in pine foliage litter fall over the drought period, but substantial variation in other litter fall components. Precipitation-runoff (P-RO) relationships indicated less variation in evapotranspiration (ET) over the drought period than predicted by simulation modeling. The discrepancy between measured and modeled ET may be related to the importance of stored soil water to streamflow, which dampens P-RO ET estimates. Regression analyses showed that growing-season water potential explained as much as 61 percent of the variation in annual basal area growth. No significant relationships were established with climatic variables alone.

676. **Vose, James M.; Swank, Wayne T.; Taylor, Randolph W.; Dashek, William V.; Williams, Arthur L. 1989.** Foliar absorption of ^{15}N labeled nitric acid vapor (HNO_3) in mature eastern white pine (*Pinus strobus* L.) In: Delleur, Jacques W., ed. Atmospheric deposition: symposium of the 3d scientific assembly of the IAHS; 1989 May 10-12; Baltimore, MD. IAHS Publ. 179. Oxfordshire, UK: IAHS Press: 211-219.

Foliage of mature white pine in cuvettes was exposed to 50 ppb ^{15}N labeled nitric acid vapor ($H^{15}NO_3$) for 4 to 12 hours to quantify foliar absorption. Net photosynthesis, transpiration, and leaf conductance were measured and foliage was observed with a scanning electron microscope (SEM). Physiological data were variable, but results indicated that transpiration and leaf conductance were reduced after exposure. Potential mechanisms include a humidity buildup within the cuvette (e.g. cuvette humidity was 7 to 20 percent higher than ambient conditions), and the direct effects of $H^{15}NO_3$ exposure. SEM of young foliage after one exposure revealed substantial cuticular disruption, which may have enhanced ^{15}N movement across the cuticle. Nitrogen-15 was absorbed in all exposures, with rates ranging from 0.00925 to 0.15650 μg $^{15}N/g$ foliage/exposure hour. Extrapolation to the entire canopy resulted in an estimated foliar uptake of 5.5 kg N/ha/yr. This represents approximately 10 percent of the annual canopy N requirement.

677. **Waggoner, P. E.; Hewlett, J. D. 1965.** Test of a transpiration inhibitor on a forested watershed. Water Resources Research. 1: 391-396.

The glyceryl half-ester of decenylsuccinic acid (GlOSA) closes tree stomata when sprayed directly on the undersides of leaves. At Coweeta, a 12 percent reduction in transpiration might be detected as a significant increase in streamflow. Two sprays of 50 lb of GlOSA in water applied to 30 acres of one watershed from a helicopter produced little deposit on the undersides of leaves and no clear evidence of stomatal closure. Observed increases in streamflow were statistically insignificant.

678. **Waide, J. B. 1988.** Forest ecosystem stability: revision of the resistance-resilience model in relation to observable macroscopic properties of ecosystems. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 383-405.

The resistance-resilience model of ecosystem relative stability, or response to disturbance, has provided part of the conceptual foundation for ecosystem research at Coweeta. It has also provided a point of departure for analyzing responses of stream ecosystems to experimental disturbances and longterm forest responses to intensive management. However, both methodological and conceptual criticisms of this model have been published. Also, recent advances in ecosystem science alter the theoretical basis of the model. This chapter presents a revised interpretation of the resistance-resilience model in relation to the theoretical conceptualization of ecosystems as hierarchical biogeochemical systems.

679. **Waide, J. B.; Caskey, W. H.; Todd, R. L.; Boring, L. R. 1988.** Changes in soil nitrogen pools and transformations following forest clearcutting. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 221-232.

Coweeta research on forest productivity and nutrient cycling focused on nitrogen fluxes through forested watersheds, nitrogen cycling through vegetation pools, nitrogen dynamics in forest litter layers, and biological nitrogen transformations in forest litter layers and soils. A compartment model was implemented to predict consequences of intensive management on forest productivity and nitrogen cycling. When earlier research was completed, data on changes in nitrogen dynamics immediately following forest disturbances were not available for any forested watershed at Coweeta. Such data were important to verify model predictions and to document both the extent of disruption of forest nitrogen cycling following disturbance and the patterns, rates, and mechanisms of forest recovery. This chapter summarizes select results of a forest clearcutting experiment focusing on changes in soil nitrogen storages and transformations at the watershed scale.

680. **Waide, Jack B.; Swank, Wayne T. 1976.** Nutrient recycling and the stability of ecosystems: implications for forest management in the Southeastern United States. In: America's renewable resource potential - 1975: the turning point: Proceedings of the 1975 national convention of the Society of American Foresters; 1975 September 28 - October 2; Washington, DC. Washington, DC: Society of American Foresters: 404-424.

A conceptual framework has guided research on elemental cycles on forested watersheds at Coweeta. This basic framework was applied to analyses of the nitrogen cycle in two important southeastern forest ecosystem types.

681. **Waide, Jack B.; Swank, Wayne T. 1977.** Simulation of potential effects of forest utilization on the nitrogen cycle in different southeastern ecosystems. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 767-789.

Forest harvesting methods may alter both quality of stream water draining forested lands (the offsite response) and sustainable productivity of forests being managed (the onsite response). Results from Coweeta suggest that longterm changes in water quality are not likely to result from current management practices, but effects on sustainable yield are unknown. Simulation models of nitrogen cycling were used to assess potential effects of several management alternatives on sustainable productivity and elemental cycling. Responses of nitrogen dynamics in oak-hickory and loblolly pine forests to simulated merchantable-stem and complete-tree harvests with several rotation lengths were examined. Results suggest that some management practices may lead to longterm alterations of nitrogen cycling and productivity, and that conclusions from such simulation studies will depend on how elemental cycling models are conceptualized.

682. **Waide, Jack B.; Webster, Jackson R. 1976.** Engineering systems analysis: applicability to ecosystems. In: Patten, B. C., ed. Systems analysis and simulation in ecology. New York: Academic Press: 329-371. Vol. 4.

Four general classes of systems analysis appear to have potential benefit in ecology. Time domain analysis involves investigation of the timing and magnitude characteristics of signals fluxing through systems. A second broad class of analysis, frequency domain analysis, concentrates on the ability of systems to attenuate (or amplify) and phase shift sinusoidal inputs. The third category, stability analysis, seems very relevant to ecosystem theory, though stability considerations in ecology have often been plagued by vague and nonequivalent definitions. Finally, techniques of sensitivity analysis are examined in detail. The authors conclude that the objectives of systems analysis in ecology and engineering are very different. Engineers are interested in designing systems, whereas ecologists must attempt to analyze existing systems. Thus, many systems engineering methodologies either may not be applicable to ecosystem analysis or may require modification before they can be applied.

683. **Walbridge, M. R.; Richardson, C. J.; Swank, W. T. 1991.** Vertical distribution of biological and geochemical phosphorus subcycles in two southern Appalachian forest soils. Biogeochemistry. 13: 61-85.

Al, Fe, and P fractions were measured by horizons in two Southern Appalachian forest soil profiles and compared with solution PO_4 removal in chloroform-sterilized and nonsterilized soils to determine whether biological and geochemical P subcycles were vertically stratified in these soils. Because organic matter can inhibit Al and

Fe oxide crystallization, concentrations of noncrystalline (oxalate-extractable) Al (Al_0) and Fe (Fe_0), and concomitantly P sorption, might be greatest in near-surface mineral (A) horizons of these soils. Al_0 and Fe_0 reached maximum concentrations in forest floor and near-surface mineral horizons, declined significantly with depth in the mineral soil, and were highly correlated with P sorption capacity. Combined with previous estimates of plant root distributions, data suggest that biological and geochemical P subcycles are not distinctly vertically stratified in these soils. Plant roots, soil micro-organisms, and P-sorbing minerals all reach maximum relative concentrations in near-surface mineral horizons, where they are likely to compete strongly for PO_4 available in solution.

684. **Walker, W. J.; Cronan, C. S.; Bloom, P. R. 1990.** Aluminum solubility in organic soil horizons from northern and southern forested watersheds. Soil Science Society of America Journal. 54: 369-374.

This study determined the influence of organic matter on the solubility of Al in organic soil horizons from Coweeta WS40 and other southern and northern forested areas. Results showed that the equilibrium solubility of Al was dependent on solution pH and the degree to which the soil organic matter was saturated with Al. Al solubility was always less than that predicted from the solubility of natural gibbsite or kaolinite and Al solubility was governed by an ion-exchange reaction between H and Al and the organic matter. No differences were noted when the soils were compared on a regional basis.

685. **Wallace, J. B. 1988.** Aquatic invertebrate research. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 257-268.

This chapter reviews aquatic invertebrate investigations at Coweeta and addresses future opportunities for longterm ecological research at Coweeta. Aquatic invertebrate studies at Coweeta have traditionally focused on the effects of forest disturbance on stream ecosystems. In contrast, undisturbed Coweeta streams tend to retain a large portion of their coarse particulate organic matter inputs. The biota, dominated by shredder biomass, exploit these retentive characteristics by feeding on the retained matter and convert it to fine particles, which are more easily entrained and transported downstream. To understand responses of many species to disturbance and their role in energy flow and nutrient cycling, studies must provide more data on life cycles and species-specific growth rates, feeding habits, and bioenergetic efficiencies.

686. **Wallace, J. B.; Cuffney, T. F.; Goldowitz, B. S.; Chung, K.; Lugthart, G. J. 1991.** Long-term studies of the influence of invertebrate manipulations and drought on particulate organic matter export from headwater streams. Verhandlungen Internationale Vereinigung fur Theoretische und Angewandte Limnologie. 24: 1676-1680.

Most energy inputs to small headwater streams in forested regions are coarse particulate organic matter (CPOM) from the surrounding forest, while outputs are fine particulate organic matter (FPOM) and dissolved organic matter (DOM). The biota, including microbes, play an important role in conversion of CPOM. In 1980, one of two adjacent first-order streams was treated with an insecticide that altered the community structure from one dominated by large shredders to one dominated by collector-gatherers and some predators. Rates of leaf litter processing and seston concentrations were significantly lower following treatments. Within 2 years after treatment ceased, restoration of shredder biomass and FPOM concentrations occurred. During the following period, the basin experienced its most severe drought in 54 years of record, which reduced the stream's ability to transport CPOM.

687. **Wallace, J. B.; Huryn, A. D.; Lugthart, G. J. 1991.** Colonization of a headwater stream during three years of seasonal insecticidal applications. Hydrobiologia. 211: 65-76.

Insects recolonized a small headwater stream in the Southern Appalachian Mountains after it was treated along its entire length with an insecticide with methoxychlor. Initial treatment (December 1985) resulted in massive insect drift. Applications continued seasonally for 3 years, and drift was measured during each treatment. Taxonomic composition of the drift indicated several responses: (1) Some taxa were eliminated, (2) a number of taxa occurred only sporadically following initial treatment, (3) early instars for some taxa showed seasonal occurrences that closely paralleled known life cycles and flight periods of adults, (4) some long-lived taxa survived and exhibited distinct growth through several treatment periods, (5) some taxa which were not present at the time of initial treatment appeared during the experiment.

688. **Wallace, J. B.; O'Hop, Joe. 1979.** Fine particle suspension feeding capabilities of *Isonychia* spp. (Ephemeroptera: Siphlonuridae). Annals of the Entomological Society of America. 72: 353-357.

Stream-inhabiting mayflies belonging to the genus *Isonychia* possess a well-developed fringe of long setae on their forelegs that is used to filter particulate materials suspended in the water column. This paper reports a mechanism, composed of two different types of microtrichia, that latches the long filtering setae to adjacent setae. This coupling mechanism results in an effective pore size of 0.1 to 0.7 μm for portions of the filtration device. Both ultrastructure of the filtering mechanism and foregut particle size analysis indicate that *Isonychia* are capable of feeding on much smaller particles than was previously suspected.

689. **Wallace, J. B.; Woodall, W. R., Jr.; Sherberger, F. F. 1970.** Breakdown of leaves by feeding of *Peltoperla maria* nymphs (Plecoptera: Peltoperlidae). Annals of the Entomological Society of America. 63: 562-567.

Nymphs of *Peltoperla maria* Needham and Smith were exposed to 15 species of autumn-shed leaves in the laboratory. The insects fed on the cuticle and mesophyll

of the leaves, leaving most of the vascular system intact. The insects consumed leaves in amounts (by dry weight) in excess of their dry body weight in a 2-week period. Feeding studies revealed that *P. maria* has definite preferences for specific kinds of leaves. Higher tannic acid content of water from feeding containers was found, apparently a result of increased leaching from the finely ground leaf material in the fecal pellets.

690. **Wallace, J. Bruce. 1970.** A new species of *Psilotreta* from North Carolina (Trichoptera: Odontoceridae) Entomological News. 81: 243-245.

A survey of the Trichoptera of the Coweeta Hydrologic Laboratory, resulted in the discovery of a new species of *Psilotreta* Banks from the Southern Appalachians. This description will give workers in aquatic biology, especially those concerned with rearing insects and using the metamorphotype technique, a more accurate determination of species in this genus in the Eastern United States. This speciesis named for H. H. Ross, who has contributed much to the knowledge of the North American Trichoptera fauna.

691. **Wallace, J. Bruce. 1975.** *Arctopsyche*: the larval retreat and food of *Arctopsyche*; with phylogenetic notes on feeding adaptations in Hydropsychidae larvae (Trichoptera). Annals of the Entomological Society of America. 68: 167-173.

Arctopsyche larvae generally construct cornucopia-shaped dwellings at the top and sides of large rocks in fast-flowing mountain streams and spin a capture net across a U-shaped frame at the anterior end of the larval abode. The individual meshes of mature larval capture nets are the largest found to date in the Hydropsychidae. The structure of the nets and larval abodes supports the placement of the Arctopsychinae as primitive Hydropsychidae. In the evolution of hydropsychid larvae, there is a tendency toward more complicated larval feeding structures and smaller capture-net mesh sizes.

692. **Wallace, J. Bruce. 1982.** Some aspects of net-spinning trichopteran diversity. In: Discovery processes and scientific productivity: Symposium celebrating the 20th anniversary of the Department of Entomology at Virginia Polytechnic Institute and State University; 1979 June 29; Blacksburg, VA. Blacksburg, VA: College of Agriculture, Virginia Polytechnic Institute and State University: 45-64.

Nets spun by larvae of the Hydropsychoidea are used to capture drifting food materials in streams. Nets allow these filter feeders to exploit food materials, which are produced in many diverse habitats and made available to them by the stream current. Both net area and mesh size differ among species and instars within species. This fundamental adaptation has important implications that relate to space, food and temporal variations in life cycles. Large meshed capture nets are located in higher current velocities than smaller meshed nets. Faster velocities are associated with increased carnivorous feeding by larvae. Net-spinning caddisfly production is apparently food-limited in certain habitats while spatial limitations are imposed in other habitats. Differences in mesh size may have significance to both food and spatial limitations.

693. **Wallace, J. Bruce. 1989.** Structure and function of freshwater ecosystems: assessing the potential impact of pesticides. In: Voshell, J. R., Jr., ed. Using mesocosms to assess the aquatic ecological risk of pesticides: theory and practice. Misc. Publ. 75. Entomological Society of America: 4-17.

Animal communities play significant roles in the processing of organic matter and nutrient cycling within lentic and lotic ecosystems. Assessing the indirect effects on the ecosystem that result from the direct effects of pesticides on the biota is a major task. Using specific examples of indirect effects of pesticides on aquatic ecosystems, needs for mesocosm and ecosystem-level testing of pesticides are discussed.

694. **Wallace, J. Bruce. 1990.** Recovery of lotic macroinvertebrate communities from disturbance. Environmental Management. 14(5): 605-620.

Ecosystem disturbances produce changes in macrobenthic community structure (abundances, biomass, and production) that persist from a few weeks to many decades. Examples with longterm effects include contamination, physical changes to habitat, and altered energy inputs. Stream size, retention, and local geomorphology may ameliorate the influence of disturbances. Disturbances can alter food webs and may select for favorable genotypes. The ability of macroinvertebrates to recolonize denuded stream habitats may vary greatly depending on life histories, dispersal abilities, and position along the stream length. Although downstream drift is the most frequently cited mechanism of invertebrate recolonization following disturbance in middle- and larger-order streams, evidence shows aerial recolonization to be potentially important in headwater streams. Successful aerial recolonization depends on the timing of disturbance relative to age class and flight periods of various taxa.

695. **Wallace, J. Bruce; Cuffney, T. F.; Lay, C. C.; Vogel, D. 1987.** The influence of an ecosystem-level manipulation on prey consumption by a lotic dragonfly. Canadian Journal of Zoology. 65: 35-40.

Pesticide application to a small headwater stream resulted in massive invertebrate drift and altered community structure with respect to both biomasses and densities. The community changed from one dominated by insects to one dominated by noninsects. Insects represented 71 to 78 percent of total abundance and about 95 percent of total biomass in an adjacent reference stream during 2 years of study. During the initial treatment year, insects, mainly Chironomidae, composed less than 20 percent of total invertebrate biomass (<10 percent of abundance) in litterbags in the treatment stream. Within 2 years of the initial disturbance, invertebrate biomass in the treatment stream was again dominated by insects. Data indicate that generalist predators can readily shift to alternative prey when confronted by massive changes in community structure.

696. **Wallace, J. Bruce; Cuffney, T. F.; Webster, J. R.; Lugthart, G. J.; Chung, K.; Goldowitz, B. S. 1991.** Export of fine organic particles from headwater streams: effects of season, extreme discharges, and invertebrate manipulation. Limnology and Oceanography. 6(4): 670-682.

Export of fine particulate organic matter (FPOM) was measured from streams draining watersheds WS53, WS54, and WS55 at Coweeta Hydrologic Laboratory for 5 years, encompassing the driest and wettest years of the past 55-year record. Macroinvertebrate populations in WS54 were reduced for 3 years by seasonal treatments with insecticide. Macroinvertebrate reduction altered the magnitude of FPOM export during storms, the seasonal pattern of export, and the annual export of FPOM. During pesticide treatment, FPOM concentrations decreased abruptly, remained well below those of reference streams for the 3-year treatment period, and then increased during the first year of recovery. Macroinvertebrate reduction resulted in an estimated 170 to 200-kg loss in FPOM export during the 3 years of treatment and first year of recovery. Annual export of FPOM was strongly related to annual discharge, but the impact of biotic manipulation on FPOM export in WS54 was at least as great as that produced by extreme high and low discharges. More export per unit maximum discharge occurred in summer from reference streams and WS54 during untreated years. During treatment years, export per unit maximum discharge was lowest in summer at WS54. Concentrations of FPOM measured during storms showed increasing concentrations with increasing discharge in all streams; however, much more FPOM was suspended in the reference streams than in WS54.

697. **Wallace, J. Bruce; Gurtz, Martin E. 1986.** Response of *Baetis* mayflies (Ephemeroptera) to catchment logging. The American Midland Naturalist. 115(1): 25-41.

Following clearcutting of a Southern Appalachian hardwood catchment, standing stock densities and biomass of *Baetis* spp. increased in four stream substrate types (rock face, cobble riffle, pebble riffle and sandy reach) compared to those of a nearby undisturbed reference stream. *Baetis* production in the stream draining the clearcut catchment averaged 17.6 times higher than that of the reference stream. Diatoms comprised the most important food in each stream, with a significant increase in diatom consumption in the stream draining the clearcut catchment. Sampling 4 and 5 years following the clearcut indicates significant declines in *Baetis* populations of the clearcut stream that coincided with a tenfold decrease in primary productivity. *Baetis* spp. comprise a minor component of the standing stock biomass in most headwater streams of the region. However, with disturbances such as clearcutting, they respond quickly to exploit increases in autochthonous production and assume major roles in energy processing.

698. **Wallace, J. Bruce; Gurtz, Martin E.; Smith-Cuffney, F. 1988.** Long-term comparisons of insect abundances in disturbed and undisturbed Appalachian headwater streams. Verhandlungen Internationale Vereinlgung fur Theoretische und Angewandte Limnologie 23: 1224-1231.

Surrounding forests exert important influences on headwater stream ecosystems. Five-year substrate-specific changes in invertebrate abundances and trophic structure were examined in two streams draining clearcut and forested catchments. Benthic organic matter and invertebrates (by functional groups) varied across bedrock, cobble, pebble, and sand substrates. Except for shredders, abundances were greater in the fifth year after cutting. Results emphasize the importance of considering substrate in a sampling regime and suggest that extremely longterm studies will be needed to document the return of biota to predisturbance configuration.

699. **Wallace, J. Bruce; Lugthart, G. John; Cuffney, Thomas F.; Schurr, Gretchen A. 1989.** The impact of repeated insecticidal treatments on drift and benthos of a headwater stream. Hydrobiologia. 179: 135-147.

A small, first-order Appalachian Mountain stream received successive treatments with the insecticide methoxychlor. Despite an application for 4 hours, only 1.6 percent of the insecticide was exported to downstream reaches for a 31 hour period during and following treatment. Most of the insecticide was incorporated into sediments of the streambed. During the initial treatment, massive drift of >950,000 organisms occurred from a stream area of about 144 m^2. Numerically, collector-gatherer taxa dominated drift. Biomass of drift was dominated by shredders. Compared with pretreatment benthic abundances, insects were reduced by 75 percent following the initial treatment in December 1985, and 85 percent following an additional treatment in March 1986. Benthic abundances of noninsect taxa showed no significant changes.

700. **Wallace, J. Bruce; Malas, Diane. 1976.** The fine structure of capture nets of larval Philopotamidae (Trichoptera) with special emphasis on *Dolophilodae distinctus*. Canadian Journal of Zoology. 54: 1788-1802.

Philopotamid larvae spin, in flowing waters, capture nets that have the smallest mesh-opening sizes recorded among trichopterans. Saclike nets of final-instar *Dolophilodes distinctus* are up to 6 cm long and 8 to 15 cm in circumference. Both larval nets and mesh-opening sizes increase with instar, those of final instars being about 0.5 by 5.5 μm. Based on scanning electron microscope examination, a probable net construction sequence is proposed. Nets of a *Wormaldia* sp. consisted of several layers of elongate rectangular meshes. Larval nets of *Chimarra* spp. have both elongate rectangular mesh-opening shapes and nets apparently consisting of randomly arranged silk strands.

701. **Wallace, J. Bruce; Malas, Diane. 1976.** The significance of the elongate rectangular mesh found in capture nets of fine particulate filter feeding Trichoptera larvae. Archiv fur Hydrobiologie. 77: 205-212.

Striking similarities exist in capture net mesh shapes of fine particle feeding Trichoptera larvae, even among genera in families that are not closely related phylogenetically. The capture nets of these fine particle feeders have elongate rectangular mesh openings. There are several important consequences associated with this type of mesh design.

702. **Wallace, J. Bruce; Merritt, Richard W. 1980.** Filter-feeding ecology of aquatic insects. Annual Review of Entomology. 25: 103-132.

Filter feeders are organisms that have evolved various sieving mechanisms for removing particulate matter from suspension. Several groups of aquatic insects, with habitats ranging from high elevation streams to saltwater estuaries, use this feeding method and consume significant quantities of suspended material (seston), including living organisms and both organic and inorganic detritus. Filter-feeding insects constitute important pathways for energy flow and are significant to the productivity of aquatic environments. The objectives of this article are to review the means by which filter-feeding insects obtain their food and to assess their role in aquatic ecosystems.

703. **Wallace, J. Bruce; Ross, Douglas H.; Meyer, Judy L. 1982.** Seston and dissolved organic carbon dynamics in a Southern Appalachian stream. Ecology. 63: 824-838.

Suspended particulate matter (seston) and dissolved organic carbon (DOC) were studied along a 6.4-km section of a Southern Appalachian headwater stream. Samples were collected at six sites encompassing stream orders one through four and a 635-m elevation change. No significant changes in seston concentration occurred from upstream to downstream sites. DOC/particulate organic carbon (0.45 times POM) ratios average 1. DOC concentrations (mg/L) increased over the first 2 km of stream but remained relatively constant farther downstream. Seven size classes of seston were measured. Although the mean particle size decreased downstream, the ratio of coarse particulate organic matter (CPOM) to fine particulate organic matter (FPOM) increased downstream. The ratio of benthic CPOM/suspended CPOM decreases downstream, which is apparently attributable to the lack of retention devices in higher order streams.

704. **Wallace, J. Bruce; Vogel, David S.; Cuffney, T. F. 1986.** Recovery of a headwater stream from an insecticide-induced community disturbance. Journal of North American Benthological Society. 5(2): 115-126.

Faunal assemblages, leaf litter processing rates, and seston export were followed in two streams after one was altered with an insecticide. Two years after treatment ended, the macroinvertebrate trophic structure of the treated stream community had recovered and was similar to that of the reference stream; however, major differences in taxonomic composition persisted. Some taxa that were rare or absent before treatment became locally abundant during recolonization. Other taxa, which were known to be abundant before treatment, remained absent or rare. Restoration of shredder biomass, leaf litter processing, and organic seston concentrations supports the concept that stream ecosystems are resilient to disturbance. Thus recovery of trophic function may occur in a fashion not recognizable solely by taxonomic criteria.

705. **Wallace, J. Bruce; Webster, Jackson R.; Cuffney, Thomas F. 1982.** Stream detritus dynamics: regulations by invertebrate consumers. Oecologia. 53: 197-200.

Insecticide treatment of a small Appalachian forest stream caused massive downstream insect drift and reduced aquatic insect densities to <10 percent of an untreated reference stream. Reduction in breakdown rates of leaf detritus was accompanied by differences in quantity and composition of benthic organic matter between the two streams. Following treatment, transport of particulate organic matter was significantly lower in the treated stream than in the reference stream, whereas no significant differences existed prior to treatment. Results indicate that macroinvertebrate consumers, primarily insects, are important in regulating rates of detritus processing and availability to downstream communities.

706. **Wallace, J. Bruce; Webster, Jackson R.; Lowe, Rex L. 1992.** High-gradient streams of the Appalachians. In: Hackney, Courtney, T.; Adams, S. Marshall; Martin, William A., eds. Offprints from biodiversity of Southeastern United States/aquatic communities. New York: John Wiley & Sons, Inc.: 133-191.

The Southern Appalachian region encompasses portions of nine States: West Virginia, Maryland, Virginia, Kentucky, Tennessee, North and South Carolina, Georgia, and Alabama. Within this region of abundant rainfall, extensive forests, and rugged terrain, many high-gradient streams originate. The objectives of this chapter are to (1) synthesize current knowledge relative to the biotic structure and function of high-gradient streams in the Southeast; (2) identify factors that control or regulate these systems; (3) evaluate the impact of various management practices on the biota of streams; and, (4) address immediate and longterm research needs for high-gradient streams.

707. **Wallace, J. Bruce; Webster, Jackson R.; Woodall, W. Robert. 1977.** The role of filter feeders in flowing waters. Archiv fur Hydrobiologie. 79(4): 506-532.

Net-spinning trichopteran larvae are used as examples of filter-feeding stream insects to show that various species feed upon a range of particle sizes. Individual species have evolved to crop particular sizes of particles in stream seston. The evolutionary mechanisms are discussed. The evolutionary diversity of filter feeders has important consequences for stream ecosystems that transcend the individual species involved.

708. **Wallace, L. L. 1988.** Comparative physiology of successional forest trees. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta.

Ecological Studies, vol. 66. New York: Springer-Verlag: 181-189.

Secondary forest succession when canopy openings, or gaps, follow the death of dominant trees, blowdowns, or selective cutting. Small openings play a significant role in the eastern deciduous forest, as do large openings resulting from clearcutting, forest fires, and insect infestations or diseases. Abiotic changes that occur in gaps of various sizes and physiological responses of major forest species display adaptive characteristics. Early successional forest vegetation affect ecosystem nutrient cycling processes in the Southern Appalachians by: (1) direct seasonal immobilization of nutrients in biomass, and high annual throughfall and litter fall nutrient transfers to the forest floor; (2) enrichment of N through symbiotic N fixation, immobilization, and eventual transfer of N to the forest floor; and (3) early shading and the recovery of forest floor temperature and moisture conditions, resulting in the rapid recovery of biological activities which control decomposition, mineralization, and mobility of nutrients.

709. **Wallace, L. L.; Dunn, E. L. 1980.** Comparative photosynthesis of three gap phase successional tree species. Oecologia. 45: 331-340.

Photosynthesis was measured in situ on trees growing in an open, gaplike site and under a closed canopy. Photosynthetic responses also were monitored on trees grown in the laboratory under either a high- or low-light regime or on those trees transferred from a low- to a high-light regime. All three species studied, *Liriodendron tulipifera*, *Acer rubrum* and *Cornus florida*, were able to acclimate to a high-light environment as evidenced by their higher photosynthetic rates. This acclimation was achieved by an increase in transfer conductance and was ultimately due to changes in leaf anatomy.

710. **Waring, R. H.; Rogers, James J.; Swank, W. T. 1980.** Water relations and hydrologic cycles. In: Reichle, D. E., ed. Dynamic properties of forest ecosystems. Malta: Cambridge University Press: 205-264.

The processes affecting water movement and storage in forests are basic to a detailed discussion of the structure and function of a watershed hydrologic system. The hydrologic processes are applied in a detailed computer simulation model. This model was applied to three different forested watersheds where streamflow data were available.

711. **Watwood, M. E.; Fitzgerald, J. W. 1988.** Sulfur transformations in forest litter and soil: results of laboratory and field incubations. Soil Science Society of America Journal. 52: 1478-1483.

Field incubations of litter and A-horizon soil utilizing ^{35}S-labeled inorganic sulfate were conducted in eastern white pine and hardwood forests. Samples were assayed for the capacity to form ^{35}S-labeled organic S, and in most cases these capacities were very similar to those determined in corresponding laboratory incubations. The A-horizons soils from both forests formed approximately 3.0 nmol of organic S per g dry weight of sample. Intrinsic S fractions of samples were quantified prior to and following field incubations, and organic S represented the majority of the total S in all cases. Sulfonate S and nonphosphate extractable ester sulfate were the largest organic S pools. Total C, moisture content, and throughfall sulfate concentrations during the field incubations were also determined.

712. **Watwood, M. E.; Fitzgerald, J. W.; Swank, W. T.; Blood, E. R. 1988.** Factors involved in potential sulfur accumulation in litter and soil from a coastal pine forest. Biogeochemistry. 6: 3-19.

Samples of O1/O2, A1, E2 and Bh horizons collected from a coastal pine forest were assayed for the potential capacity to adsorb and to form organic sulfur from added sulfate. The subsequent mineralization of organic S was also assayed to determine potential capacities for organic S accumulation. Organic and inorganic forms of S were quantified, as were total carbon and nitrogen levels. Of the organic S present, sulfonate-S was found to be the major component irrespective of horizon. Adsorbed and soluble S were found to be low, suggesting that loss by leaching may be an important fate of incoming sulfate at this site. Soils from the pine forest site adsorbed substantially less sulfate than those from two other sites previously shown to be S accumulating.

713. **Watwood, Mary E.; Fitzgerald, John W.; Swank, Wayne T. 1988.** Effects of moisture content on sulfate generation and retention in hardwood forest upper soil horizons. Canadian Journal of Forest Research. 18: 820-824.

The influence of moisture on organic S mineralization and the fate of both mineralization-derived and added sulfate were examined in A- and B-horizon soil samples from a hardwood forest. ^{35}S-labeled sulfate or methionine was added to field-moist samples, which were then suction dried to contain between 2 and 80 percent moisture. Both added sulfate-S and sulfate-S released by methionine mineralization were incorporated into organic matter. The highest levels of organic S formed were in samples at 25 and 35 percent moisture content. The A horizon incorporated much less added sulfate under very dry conditions. The B horizon exhibited substantial decreases under both moisture extremes. At moisture contents over 30 percent, high levels of methionine mineralization were observed; at lower moisture contents mineralization decreased substantially. For soil moistures lower than 20 percent, most of the added methionine remained nonmineralized following incubation. At soil moistures between 20 and 35 percent, a portion of the added methionine was also incorporated directly into organic matter.

714. **Webb, D. P. 1977.** Regulation of deciduous forest litter decomposition by soil arthropod feces. In: Mattson, W. J., ed. The role of arthropods in forest

ecosystems. New York; Heidelberg; Berlin: Springer Verlag: 56-69.

Soil invertebrates may consume 20 to 100 percent of annual litter input, and, in so doing, produce an immense amount of excrement. Presumably, feces merely represent pulverized litter, which offers greater surface area for leaching and microbial attack. Positive feedback between microflora and soil fauna is believed to produce a slow step-by-step humification of litter as soil, litter, feces and microflora are ingested and reingested. Such litter decomposes rapidly via physical processes and, therefore, exclusion of arthropods from it has failed to show any decrease in decomposition rates.

715. **Webster, J. R.; Benfield, E. F. 1986.** Vascular plant breakdown in freshwater ecosystems. Annual Review of Ecology Systems. 17: 567-594.

This is a review of the state of knowledge of the breakdown of detritus in freshwater ecosystems derived from aquatic vascular plants and riparian trees and herbs. The relative dominance of allochthonous vs. autochthonous sources varies between stream systems and with local conditions within streams. Many low-order streams that lack canopies of riparian vegetation may be dominated by autochthonous primary production of nonvascular plant origin. Theoretical models predict increasing importance of autochthonous production by periphyton and aquatic vascular plants for middle-order streams but less importance of these sources in very large streams, mainly due to light limitations. The direct contribution of wood to stream energy budgets is minimal because wood is resistant to breakdown. However, woody debris is indirectly important because it creates habitat for aquatic organisms, promotes physical stability of the stream channel, and retards loss of more readily available food sources.

716. **Webster, J. R.; Benfield, E. F.; Golladay, S. W.; Kazmierczak, R. F., Jr.; Perry, W. B.; Peters, G. T. 1988.** Effects of watershed disturbance on stream seston characteristics. In: Swank, W. T.; Crossley, D. A., Jr., eds. Forest hydrology and ecology at Coweeta. Ecological Studies, vol. 66. New York: Springer-Verlag: 279-294.

The effects of longterm disturbances on stream function are evaluated for 7 Coweeta reference streams and 10 streams draining watersheds that had been disturbed 7 to 34 years prior to study. Conditions in forest ecosystems are reflected in the transport of particulate materials draining these watersheds. In the first few years after disturbance, inputs of sediment directly from the disturbed watershed are probably the major impact. In subsequent years, indirect effects caused by the decline of woody debris dams within the stream are of greater importance. The resulting increased erodibility of the stream channel may cause a stream disturbance that lasts much longer than any observable disturbance of the adjacent terrestrial ecosystem.

717. **Webster, J. R.; Blood, E.; Gregory, S. V.; Gurtz, M. E.; Sparks, R. E.; Thurman, M. 1985.** Long-term research in stream ecology. Bulletin of the Ecology Society of America. 66: 346-353.

Each Long Term Ecological Research Program involved with stream ecology is characterized and the nature and objectives of stream research at these sites summarized.

718. **Webster, J. R.; D'Angelo, D. J.; Peters, G. T. 1991.** Nitrate and phosphate uptake in streams at Coweeta Hydrologic Laboratory. Verhandlungen Internationale Vereinlgung fur Theoretische und Angewandte Limnologie 24: 1681-1686.

A solution of NO_2HPO_4, $NaNO_3$, and NaCl was injected into Coweeta Watersheds 6, 7, and 14 to temporarily raise nitrate and phosphate concentrations to 5 to 10 times that of background level. Samples were collected at three points downstream of each injection to determine nutrient uptake in February, March, July, and November. The contrast of mixed hardwood forest vegetation for streams was a grass to successional cover, regrowing clearcut (9 years old), and a relatively mature stand. Results show that Southern Appalachian streams are limited by availability of soluble phosphate and that phosphate is rapidly removed from solution. Nitrate is much less readily taken up. Phosphate uptake is modified by physical factors, such as velocity, depth, and temperature, but the primary mechanism is heterotrophic uptake by microbes associated with large and small particles of benthic detritus. Catchment disturbances that change detrital inputs, storage, and breakdown rates may modify patterns of nutrient retention in streams.

719. **Webster, J. R.; Golladay, S. W. 1984.** Seston transport in streams at Coweeta Hydrologic Laboratory, North Carolina, U. S. A. Verhandlungen Internationale Vereinlgung fur Theoretische und Angewandte Limnologie. 22: 1911-1919.

A stream with a high loss of particulate and dissolved organic carbon would be considered inefficient compared with another stream with less loss and high utilization (i.e., respiration) within the stream. Theoretically, seston concentrations should be related to stream power, i.e., the ability of a stream to physically entrain material from the stream-bed and to then keep it in motion. Numerous studies have demonstrated a clear relationship during storms, but attempts to relate seston concentrations during nonstorm periods to power or discharge have been largely unsuccessful. This suggests that mechanisms other than physical entrainment are responsible for seston concentrations. Seston was collected from a variety of small streams in a single area in order to better understand mechanisms determining seston transport and the effect of catchment disturbance on seston concentrations was examined during nonstorm periods.

720. **Webster, J. R.; Golladay, S. W.; Benfield, E. F.; D'Angelo, D. J.; Peters, G. T. 1990.** Effects of forest disturbance on particulate organic matter budgets of small streams. Journal of the North American Benthological Society. 9(2): 120-140.

Organic matter dynamics were studied in five streams at Coweeta. Litter inputs to three streams draining logged watersheds were significantly lower than to the two reference streams. Organic matter budgets were calculated from input, standing crop, and export data. This synthesis showed that forest disturbance has increased export, has accelerated turnover of benthic particulate organic matter, and is depleting benthic material. These changes are related primarily to the decline of woody debris dams in the disturbed streams. Nonwoody benthic organic material was generally lower in disturbed streams and woody benthic material was substantially higher. Particulate organic matter transport was measured intensively during storms. A model to estimate annual transport related particulate concentration to the rate of increase in flow during storms, time since peak storm discharge, and average baseflow concentration. Results showed that disturbed streams exported significantly more particulate organic matter, mainly during storms.

721. **Webster, J. R.; Golladay, S. W.; Benfield, E. F.; Meyer, J. L.; Swank, W. T.; Wallace, J. B. 1992.** Catchment disturbance and stream response: an overview of stream research at Coweeta Hydrologic Laboratory. In: Boon, P. J.; Calow, P.; Petts, G. E., eds. River conservation and management. Chichester, UK: John Wiley & Sons Ltd: 231-253.

Processes in headwater streams are closely tied to the terrestrial ecosystems of their catchments, thus disturbances to the catchment may have severe impacts on these streams. For over 50 years, researchers at Coweeta Hydrologic Laboratory in the southern Appalachian Mountains of North Carolina, have been studying the effects of land management practices on water quantity and quality in small, mountain streams. Since 1968, these longterm studies have been accompanied by investigations by aquatic ecologists on management impacts to stream ecosystem structure and function. Stream studies have emphasized macroinvertebrates, organic matter dynamics, dissolved organic carbon, microbial processes, and instream nutrient dynamics. Results have shown the importance of hydrologic conditions (large storms, droughts), substrate characteristics, and woody debris dams. Stream ecosystem response to catchment disturbance is quite different from response to direct disturbance. Following a catchment disturbance such as logging, stream recovery is limited by the rate at which catchment vegetation recovers. Streams in this area continue to be disturbed for more than 100 years following major catchment modification.

722. **Webster, J. R.; Gurtz, M. E.; Hains, J. J.; Meyer, J. L.; Swank, W. T.; Waide, J. B.; Wallace, J. B. 1983.** Stability of stream ecosystems. In: Barnes, James R.; Minshall, G. Wayne, eds. Stream ecology. New York: Plenum Publishing Corporation: 355-395.

The ability of ecosystems to recover from external disturbances (stability) is a fundamental property of these systems. Quantification of stability and understanding of the mechanisms behind recovery are current areas of major ecological research. This overview of the stability concept used in ecology includes a more specific discussion of its application to stream ecosystems. A case study is used where the stability of small streams disturbed by watershed logging is compared to stability of the adjacent disturbed forest ecosystem.

723. **Webster, J. R.; Swank, W. T. 1985.** Stream research at Coweeta Hydrologic Laboratory. In: Proceedings of the specialty conference on hydraulics and hydrology in the small computer age; 1985 August 12-17; Lake Buena Vista, FL. New York: American Society of Civil Engineers, Hydraulics Division: 868-873.

Stream research at Coweeta has been directed primarily toward an understanding of longterm responses to logging. Effects of logging on streams include physical alterations of habitat, changes in hydrologic, chemical, and thermal characteristics of the water, and changes in food resources. Stream studies are summarized with emphasis on how forest management, particularly logging, affects the structure and function of small stream ecosystems.

724. **Webster, J. R.; Swank, W. T. 1985.** Within-stream factors affecting nutrient transport from forested and logged watersheds. In: Blackmon, B. G., ed. Proceedings of forestry and water quality: a mid-South symposium; 1985 May 8-9; Little Rock, AR. Monticello, AR: University of Arkansas, Department of Forest Resources: 18-41.

Nutrient concentrations in stream water are the result not only of inputs from the adjacent forest but also of instream modifications of these inputs. Important instream process include autotrophic and heterotrophic uptake, macroinvertebrate particle generation, and retention of dissolved and particulate nutrients by woody debris. Major changes in these processes occur following forest logging. As a result of these changes, streams in the southern Appalachian Mountains may have their lowest ability to retain nutrients 20 to 30 years after logging.

725. **Webster, Jackson R. 1977.** Large particulate organic matter processing in stream ecosystems. In: Correll, David L., ed. Watershed research in eastern North America: a workshop to compare results; 1977 February 28-March 3; Edgewater, MD. Edgewater, MD: Smithsonian Institution: 505-526.

The stream ecosystems of eastern deciduous forests are highly adapted to their riparian terrestrial surroundings. Particulate organic matter inputs from the riparian vegetation are processed by the combined action of microbes and invertebrates and the mechanical action of flowing water. In unperturbed Coweeta streams, processing efficiency is 95 to 99 percent. Processing efficiency is less in watersheds where the vegetation has been disturbed. Comparison of Coweeta data with other studies suggests a greater processing efficiency in southeastern than northeastern streams.

726. **Webster, Jackson R. 1978.** Hierarchy theory and ecosystem models. In: Halfon, E., ed. Theoretical systems ecology. New York: Academic Press: 119-129.

The relevance of the hierarchy concept in biology has been questioned, but it is nevertheless a useful way to organize the perception of nature. The hierarchical ordering of nature is both structural and dynamic, with the vertical separation of levels dependent on behavioral frequencies and the horizontal separation the result of the degree of interaction between systems. Within this hierarchy of natural systems, one can perceive both upward and downward causation. This perception provides a philosophical midground between holism and reductionism. At the ecological levels of organization, ecosystems are comprised of interacting organisms. Communities and populations are not natural systems and can best be recognized as subunits of ecosystems. Advances in ecosystem ecology must proceed from an understanding of ecosystem level behaviors and laws.

727. **Webster, Jackson R. 1983.** The role of benthic macroinvertebrates in detritus dynamics of streams: a computer simulation. Ecological Monographs. 53(4): 383-404.

Detritus dynamics in Big Hurricane Branch, a second-order stream at Coweeta were simulated with a computer model using data from a variety of Coweeta stream studies. The model was used to evaluate the role of macroinvertebrates in the stream. Macroinvertebrates accounted for only a small portion of the respiration of detritus; their major role was conversion of benthic detritus into transported detritus. Based on an annual budget, macroinvertebrates decrease the efficiency of detritus processing in low-order streams, because they increase transport loss. On a longer time scale, however, macroinvertebrates prevent accumulation of large amounts of detritus in the stream and major losses during infrequent large storms. By stabilizing longterm detritus export dynamics, they provide an important link between lower-order and higher-order streams.

728. **Webster, Jackson R.; Crossley, D. A., Jr. 1978.** Evaluation of two models for predicting elemental accumulation by arthropods. Environmental Entomology. 7(3): 411-417.

Two different models have been proposed for predicting elemental accumulation by arthropods. Parameters of both models can be quantified from radioisotope elimination experiments. Analysis of the two models shows that both predict identical elemental accumulation for a whole organism, though differing in the accumulation in body and gut. Both models were quantified with experimental data from ^{134}Cs and ^{85}Sr elimination by crickets. Computer simulations of radioisotope accumulation were then compared with actual accumulation experiments. Neither model showed exact fit to the experimental data, though both showed the general pattern of elemental accumulation.

729. **Webster, Jackson R.; Patten, Bernard C. 1979.** Effect of watershed perturbation on stream potassium and calcium dynamics. Ecological Monographs. 49: 51-72.

Three small streams at Coweeta (an old field, a pine plantation, and a hardwood forest watershed) were investigated to determine effects of watershed perturbation on K and Ca dynamics in the stream ecosystems. Data collected included measurements of litter fall inputs, large particulate organic matter and benthic organism standing crops, large particulate organic matter and organism drift, and insect emergence. The isotopes, ^{85}Sr and ^{134}Cs were used to estimate detritivore ingestion and elimination rates of Ca and K, respectively. Watershed perturbations had altered stream inputs and caused accompanying changes in the stream fauna. Results indicated that the perturbed streams had less efficient physical processing of allochthonous inputs, but greater biological utilization of inputs. The streams exhibited high resilience to perturbation with complete recovery limited by the recovery rate of allochthonous inputs.

730. **Webster, Jackson R.; Waide, Jack B. 1982.** Effects of forest clearcutting on leaf breakdown in a Southern Appalachian stream. Freshwater Biology. 12: 331-344.

Effects of forest clearcutting on rates of leaf breakdown were studied in Big Hurricane Branch, a second-order stream located at Coweeta. Breakdown rates of leaves of three tree species were measured in the stream before, during and after the catchment was clearcut. Breakdown rates of all three leaf species were slowed during clearcutting and accelerated later. Following logging, the breakdown rate of dogwood leaves was equal to the pretreatment rate, and white oak and rhododendron leaves broke down faster than prior to treatment. The slow breakdown during treatment was attributed to burial of the leaf packs in sediment. Subsequent acceleration may have been due to a lack of alternative food sources for invertebrate detritivores.

731. **Webster, Jackson R.; Waide, Jack B.; Patten, Bernard C. 1975.** Nutrient recycling and the stability of ecosystems. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symposium Series Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 1-27. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

A theoretical perspective on ecosystems is elaborated which relates alternative strategies of stability to observable and measurable attributes of ecosystems. Arguments are presented for viewing nutrient cycling as positive feedback. Attention is focused on two aspects of relative stability: resistance and resilience. A linear ecosystem model that embodies these concepts is discussed, and four relative stability indexes are derived. Random matrices, subject to mass-conservation limitations, and hypothetical ecosystem models, constructed according to a characterization of alternative properties of nutrient cycles, are analyzed to examine relationships between the relative stability indexes and specific properties of nutrient cycles. The theory put forth in this paper is seen as a rigorous, operational

approach to ecosystems, is testable by both observation and experimental analysis.

732. **Webster, Jackson R.; Wallace, J. Bruce. 1975.** Productivity of southeastern stream ecosystems. In: Proceedings, symposium on trout habitat research and management; 1974 September 5-6; Cullowhee, NC. Boone, NC: Appalachian Consortium Press: 64-78.

Streams differ from terrestrial ecosystems in a number of characteristics. Most studies indicate the main source of energy to streams is in allochthonous inputs. A generalized Southeastern United States trout stream model is proposed and examples of organisms performing various functions are described.

733. **Wells, Martha J. M. 1982.** The effect of silanol masking on the recovery of picloram and other solutes from a hydrocarbonaceous pre-analysis extraction column. Journal of Liquid Chromatography. 5(12): 2293-2309.

The recoveries of picloram, picloram-methylester, hexazinone, benzene, and acetophenone from aqueous samples were studied using a commercially available hydrocarbonaceous preanalysis extraction cartridge, both with and without tetrabutylammonium hydrogen sulfate (TBAHS) in the eluent. Extraction efficiency was found to be dependent on sample loading volume. The results suggest a mixed mechanism of retention involving both silanophilic and hydrophobic interactions in the absence of tetrabutylammonium ion. The ability of TBAHS to mask surface silanol groups and/or ion-pairing with counterionic solutes may explain the observations. Chromatograms of the solutes obtained on a ^{18}C bonded analytical column in both the presence and absence of TBAHS are also presented.

734. **Whelan, D. E. 1957.** Effects of land use on streamflow. Journal of the Alabama Academy of Science. 29(4): 55-60.

Present knowledge of the effects of land use and treatment on streamflow is summarized. The basic concepts of land use and ground-water hydrology are discussed in order to show how soil and vegetal cover influence the disposition of precipitation.

735. **White, David L.; Haines, Bruce L.; Boring, Lindsay R. 1988.** Litter decomposition in Southern Appalachian black locust and pine-hardwood stands: litter quality and nitrogen dynamics. Canadian Journal of Forest Research. 18: 54-63.

Litter decomposition and nitrogen (N) dynamics were compared for two forest stands by monitoring weight loss, N concentration, and litter quality for 863 days. Species studied were *Robinia pseudoacacia*, *Liriodendron tulipifera*, and *Rubus* spp. (leaves and stems) in a 16-year-old black locust stand and *Kalmia latifolia*, *Pinus rigida*, and *L. tulipifera* in a pine-hardwood stand. Between-stand comparison of *L. tulipifera* leaf litter indicated a significant stand effect only in weight loss in the first 8 months. Initial lignin content was highly correlated to percent weight remaining and net N immobilization. All litter types exhibited an absolute increase in lignin. *Rubus* and other understory species influenced organic matter and N accretion in these early successional systems. *Robinia pseudoacacia* leaflets decomposed slowly and contained 81 percent of their original N at day 863, explaining the longterm effect of *Robinia pseudoacacia* upon N storage in the forest floor and soil.

736. **Whitford, W. G.; Meentemeyer, V.; Seastedt, T. R.; Cromack, K., Jr.; Crossley, D. A., Jr.; Santos, P.; Todd, R. L.; Waide, J. B. 1981.** Exceptions to the AET model: deserts and clearcut forest. Ecology. 62: 275-277.

A model for decomposition of litter as a function of actual evapotranspiration (AET) and lignin content developed for temperate and boreal forest sites was tested for other ecosystems. The correlation between AET and decomposition does not necessarily apply to all vegetation types nor to severely disturbed sites. Decomposition is higher than predicted by the AET model in deserts where AET is low, and lower than predicted for a mesic clearcut forest where AET values are higher than for uncut forests.

737. **Woodall, W. R., Jr.; Wallace, J. B. 1975.** Mineral pathways in small Appalachian streams. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symposium Series Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 408-422. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Nutrient contents of benthic organisms in streams draining four small watersheds were examined. The watersheds, located in the Southern Appalachian mountains, were each a different vegetation type. Crayfish and salamanders were responsible for most of the standing-crop biomass and fluxes in the detritivore and predator compartments, respectively. An increase in potassium concentrations and a decrease in calcium and magnesium concentrations were associated with an increase in trophic levels. Since the food material was richer in calcium and magnesium than in potassium, detritivores concentrated proportionately more potassium than calcium or magnesium. The principal mechanism of potassium release from detritus was through leaching. For calcium and magnesium, the principal mechanism for release was the feeding activity of detritivores.

738. **Woodall, W. Robert, Jr.; Wallace, J. Bruce. 1972.** The benthic fauna in four small Southern Appalachian streams. American Midland Naturalist. 88: 393-407.

Monthly quantitative samples of benthic organisms were collected from streams in four different watersheds from August 1968 through July 1969. Each of the watersheds supports one of the following types of vegetation: old-field

succession, hardwood forest, white pine forest with a few hardwoods, coppice forest. The kinds of organisms in the four streams were generally similar but their relative importance varied significantly. A Duncan's multiple-range test showed significant differences in the numbers of most taxa among the watersheds. The old-field stream had the greatest abundance while the coppice stream had the greatest standing crop biomass. The white pine stream had lowest standing crops of both numbers and biomass. Most of the differences among watersheds were attributed to different inputs of allochthonous detritus.

739. **Yeakley, J. A.; Swank, W. T.; Hornberger, G. M.; Shugart, H. H. 1992.** A method of modeling source area response to climate variability. In: Hermann, Raymond, ed. Managing water resources during global change: 28th annual conference & symposium of the AWRA; 1992 November 1-5; Reno, NV. Bethesda, MD: American Water Resources Association: 211-219.

A modeling framework for understanding spatially-explicit relationships between soil moisture dynamics and streamflow generation in upland humid forested watersheds is described. The framework consists of a dynamic canopy interception module and a 2-dimensional finite element hillslope hydrology model (IHDM4) having hillslope planes objectively delineated using contour-based terrain analysis (TAPES-C). This approach is fine-scaled both in space and time allowing for the inclusion of topographic and soil heterogeneities necessary for mapping oscillations in the variable source areas of streamflow generation. The modeling framework is implemented for a small control watershed (WS 2) at the Coweeta Hydrologic Laboratory. Simulation results presented at the conference include the climate-scale response of variable source areas for hillslope cross sections to hourly climate data spanning years in which total precipitation was: (a) >20 percent above average, (b) near average, (c) >20 percent below average.

740. **Yount, J. David. 1975.** The effect of nonremoval clear-cutting and pine reforestation on the cation composition of a hardwood forest soil. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symposium Series Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 744-753. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Soil studies were conducted at Coweeta Hydrologic Laboratory, North Carolina, in a deciduous hardwood forest and in a white pine plantation established after clearcutting and decay of all previous vegetation. These studies demonstrate that the soil under the pine forest differs from soil under the control hardwood forest in the opposite direction to that expected based on relative nutrient demands of young pine forests and mature hardwood forests. The principal difference is a high calcium concentration in the pine soil compared with the control soil and, related to that, a higher pH. Cation exchange capacity and percent base saturation were also higher in the pine plantation soil.

741. **Yount, J. David. 1975.** Forest-floor nutrient dynamics in Southern Appalachian hardwood and white pine plantation ecosystems. In: Howell, Fred G.; Gentry, John B.; Smith, Michael H., eds. Mineral cycling in southeastern ecosystems; 1974 May 1-3; Augusta, GA. Symposium Series Conf-740513. Washington, DC: U.S. Energy Research and Development Administration, Technical Information Center: 598-608. [Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161].

Nutrient content and detrital biomass in the forest floor of a mature deciduous hardwood watershed and a 15-year-old white pine plantation at Coweeta Hydrologic Laboratory were followed through one complete annual cycle, May 1970 to May 1971. Total carbon storage is significantly greater in the white pine than in the deciduous hardwood forest floor. Forest-floor biomass is probably approaching a steady state in the pine plantation, as indicated by computed turnover times. Calcium content, which is on the order of 100 kg/ha in both forest floors, is higher in the hardwood forest floor than in the pine; this reflects a considerably higher concentration of calcium in hardwood litter. Magnesium content is an order of magnitude lower than calcium. Potassium and sodium levels are very similar in both forest floors. Nitrogen and phosphorus storage is considerably higher in the white pine than in the hardwood forest floor. Summer loss rates were computed for forest-floor components.

742. **Zaruba, C., reviewer. 1989.** Forest hydrology and ecology at Coweeta. Biologia Plantarum. 31(4): 318-319.

A review of the Coweeta Symposium volume.

Dissertations and Theses

743. **Abbott, David Thomas. 1980.** Woody litter decomposition at Coweeta Hydrologic Laboratory, North Carolina. Athens, GA: University of Georgia. 136 p. Ph.D. dissertation.

744. **Adler, Robert Charles. 1988.** Intervention analysis of the impact of forest harvesting on streamflow at Coweeta Hydrologic Laboratory, North Carolina. Boston, MA: Boston University. 209 p. M.S. thesis.

745. **Andrew, Tamara Lynn. 1983.** Methionine degradation in forest soils. Athens, GA: University of Georgia. 88 p. M.S. thesis.

746. **Apsley, David Kurt. 1987.** Growth interactions and comparative water relations of *Liriodendron tulipifera* L. and *Robinia pseudoacacia* L. Athens, GA: University of Georgia. 83 p. M.S. thesis.

747. **Best, George Ronnie. 1971.** Potassium, sodium, calcium, and magnesium flux in a mature hardwood forest watershed and an eastern white pine forest watershed at Coweeta. Athens, GA: University of Georgia. 88 p. M.S. thesis.

748. **Best, George Ronnie. 1976.** Treatment and biota of an ecosystem affect nutrient cycling. Athens, GA: University of Georgia. 113 p. Ph.D. dissertation.

749. **Biever, Lawrence Joseph. 1982.** The role of mycorrhizal fungi in ecosystem energetics. Athens, GA: University of Georgia. 158 p. Ph.D. dissertation.

750. **Black, Peter Elliott. 1957.** Interception in a hardwood stand. Ann Arbor, MI: University of Michigan. 90 p. M.F. thesis.

751. **Blair, John Michael. 1987.** Litter decomposition, nutrient dynamics and litter microarthropods on a clearcut and reference watershed at the Coweeta Hydrologic Laboratory in the Southern Appalachians. Athens, GA: University of Georgia. 117 p. Ph.D. dissertation.

752. **Blanton, Chantal Marie. 1989.** Canopy arthropod communities in the Southern Appalachians: impacts of forest management and drought. Athens, GA: University of Georgia. 167 p. Ph.D. dissertation.

753. **Boring, Lindsay Ross. 1979.** Early forest regeneration and nutrient conservation on a clearcut southern Appalachian watershed. Athens, GA: University of Georgia. 86 p. M.S. thesis.

754. **Boring, Lindsay Ross. 1982.** The role of black locust (Robinia pseudo-acacia L.) in forest regeneration and nitrogen fixation in the southern Appalachians. Athens, GA: University of Georgia. 173 p. Ph.D. dissertation.

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756. **Brown, Jeffrey Dana. 1985.** Growth and nutrient uptake responses to changing nutrients by plant species from a Southern Appalachian succession. Athens, GA: University of Georgia. 123 p. M.S. thesis.

757. **Chang, Chin-Sung. 1993.** Genetic structure of black locust (*Robinia pseudoacacia* L.) at Coweeta, North Carolina. Athens, GA: University of Georgia. 76 p. M.S. thesis.

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763. **Cromack, Kermit, Jr. 1973.** Litter production and decomposition in a mixed hardwood watershed and a white pine watershed at Coweeta Hydrologic Station, North Carolina. Athens, GA: University of Georgia. 160 p. Ph.D. dissertation.

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Carolina. Clemson, SC: Clemson University. 173 p. Ph.D. dissertation.

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873. **Watt, James P. C. 1965.** Development of the dye dilution method for measuring water yields from mountain watersheds. Fort Collins, CO: Colorado State University. 121 p. M.S. thesis.

874. **Webster, Jackson Ross. 1975.** Analysis of potassium and calcium dynamics in stream ecosystems on three southern Appalachian watersheds of contrasting vegetation. Athens, GA: University of Georgia. 232 p. Ph.D. thesis.

875. **White, David Lawrence. 1986.** Litter production, decomposition and nitrogen dynamics in black locust and pine-hardwood stands of the Southern Appalachians. Athens, GA: University of Georgia. 120 p. M.S. thesis.

876. **Williams, Jerry G. 1954.** A study of the effect of grazing upon changes in vegetation on a watershed in the southern Appalachian mountains. East Lansing, MI: Michigan State University. 138 p. M.S. thesis.

877. **Woodall, William Robert, Jr. 1969.** A comparison of aquatic insects in four different watersheds. Athens, GA: University of Georgia. 115 p. M.S. thesis.

878. **Woodall, William Robert, Jr. 1972.** Nutrient pathways in small mountain streams. Athens, GA: University of Georgia. 118 p. Ph.D. dissertation.

879. **Yeakley, Jon Alan. 1993.** Hillslope soil moisture gradients in an upland forested watershed. Charlottesville, VA: University of Virginia. 149 p. Ph.D. dissertation.

880. **Yehling, Donald Mark. 1985.** The canopy arthropod ecology of Southern Appalachian white pine plantations. Athens, GA: University of Georgia. 87 p. M.S. thesis.

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