USDA-Forest Service RESEARCH WORK UNIT DESCRIPTION Ref: FSM 4070	1. Number FS-SRS-4155	2. Station Southern Research Station
	3. Unit Location Stoneville, MS	

4. Research Work Unit Title
Center for Bottomland Hardwoods Research

5. Project Leader (Name and Address)
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6. Area of Research Applicability	7. Estimated Duration
Southern bottomland hardwoods, forested wetlands, riparian zones, and associated aquatic ecosystems, National, and International	5 Years

8. Mission
To provide the scientific basis for sustainable management of southern bottomland hardwood and wetland forests and associated stream ecosystems.

9. Justification and Problem Selection
The bottomland hardwood forests of the South have been termed an "endangered ecosystem" and illustrate the complexity of management challenges at multiple scales that forest managers around the world must face. Approximately half of the wetland resource in the U.S. occurs in the South, and the majority of these wetlands are forested. In addition to wetlands, non-hydric bottomlands and riparian areas occur in hydrogeomorphic settings similar to wetlands. Together these lands provide critical benefits that are fundamental to ecosystem health at multiple scales, including productivity, habitat, freshwater resources, and biodiversity. The forested wetland resource is also an integral component of commercial forestlands, where high rates of timber and fiber biomass production are possible without

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compromising environmental values. Bottomlands comprise a diverse set of forest ecosystem types which occur mostly in the floodplains of major rivers and their tributaries within the broad coastal plain stretching from Virginia to Texas. The importance to society of these floodplain forests and their associated aquatic systems is well documented. These lands are a valuable commercial forest resource in the South, they provide important environmental functions that protect freshwater resources, and they represent wildlife and aquatic habitats of national and international importance. Because bottomlands are so productive, many have been converted to agricultural uses resulting in a significant decline in acreage. Accordingly, the remaining bottomland hardwood forests are a critical economic and ecological resource.

Bottomland hardwood and wetland forests account for 15%, or 30 million acres, of the total timberlands in the southern United States. More than 90 % of these forests are privately owned. Non-industrial private landowners account for 66%, while forest industry owns about 25%. Southern bottomland hardwood forests contain about 45 billion cubic feet of growing stock, of which 160 billion board feet (International ¼ inch scale) are in sawtimber (approximately 26 billion cubic feet of growing stock). Nevertheless, many stands are understocked with commercial species. Cull trees occupy an increasing portion of the growing space of bottomland stands, with concomitant shortages in the volume of high-quality hardwood sawtimber.

The utilization and value of hardwoods in general have increased as the demand for hardwood lumber and pulpwood has risen in the 1990s. The South produces about 57% of the country's hardwood lumber, 40% of its hardwood plywood, and 60% of its pulpwood (of which an increasing amount is hardwood). The Forest Service has predicted an 80% increase in hardwood harvesting over the next 50 years. Although growth exceeds removal by a ratio of 1.4 to 1, many bottomland hardwood stands are understocked. For example, 60% of the area supports stands of less than 5000 board feet per acre, and 37% of these stands carry less than 1500 board feet per acre. This increased demand comes at a time when volume of high-quality hardwood sawtimber may be locally scarce and slow regeneration rates are a problem for most high-value species. In response, many landowners seek to manage their forests more intensively.

Research in the last decade has established the recalcitrant nature of the seeds of many prominent forest tree species and our inability, as managers, to predict the longevity of these seeds in seed banks or the species composition resulting from natural regeneration. Further, sawtimber-sized stands outnumber poletimber and sapling-seedling stands by three to one, providing many challenges to forest managers faced with growth declines and increasing levels of mortality in aging stands. Future hardwood fiber demand is projected to exceed fiber supply and very intensively managed fiber farms are being developed near processing facilities. Major insect and disease pest problems must be overcome for these fiber farms to be successful on a commercial scale, and techniques are needed to avoid or mitigate adverse environmental impacts.

Riparian ecosystems of the southern United States provide important habitats for the most diverse terrestrial and aquatic fauna on the continent. The South harbors the highest diversity of freshwater mussels in the world, and more native fishes than any other region in the United States and Canada. Forested watersheds in the South increasingly serve as the last refugia for many sensitive species of birds, nongame fishes, mussels, and other riparian-dependent wildlife. Bottomland hardwood forests provide breeding or wintering habitat for 176 bird species; an even larger number of Neotropical migratory bird species use these forests as vital migratory habitat. About 17% of southern U.S. fishes are endangered, threatened, or of special concern. The freshwater mussel fauna is experiencing an extinction crisis perhaps more severe than any other group of animals in the country. A recent review by the American Fisheries

Society concluded over 70% of native freshwater mussel taxa are imperiled. Of the 338 recognized taxa of crayfishes in North America, 326 are found in the South. In 1996, the American Fisheries Society ranked 48% of southern crayfishes as endangered, threatened, or of special concern. Two of the eight species of tree bats that occur in the South are of special concern and occur widely in bottomland hardwood forests. Clearly, the fate of southern forests and the waters they produce will play a vital role in the maintenance and recovery of the region's biodiversity.

Between 500,000 acres and 1 million acres of economically marginal farmland in the lower Mississippi River Valley will be restored to forest trees by the year 2005. More effective restoration techniques are needed by public and private land managers to successfully recapture wetland functions lost when these lands were converted to row crops. Techniques are needed for restoring mixed species stands, including understory and midstory species; for establishing populations of rare and endangered plant species; and for restoring riparian and aquatic communities lost when river systems were modified. The need for research is immediate and continuing, as illustrated by results from monitoring FY 92 Wetlands Reserve Program restoration in Mississippi, where over 90% of the 10,000 acres failed to regenerate adequately, after a federal investment of $4.5 million.

In addition to conversions to agricultural and urban uses, many southern bottomland hardwood and wetland forest stands have deteriorated in quality and growth potential because of heavy cutting without regard for proper silvicultural technique. Stands have deteriorated due to periodic diameter limit cutting; many stands are dominated by slow-growing, shade intolerant species of less value for wildlife or timber. There is especially a lack of regeneration by oaks, which as a group are the most valuable component of bottomland hardwood stands. Managers cannot accurately predict species composition or stocking, or be assured that the regeneration stand will contain acceptable numbers of stems of preferred species. If natural regeneration fails, there is a lack of proven information on which to make recommendations for remedial actions. Further, efforts to restore up to 1 million acres of bottomland hardwood and wetland forests on former agricultural land are hampered by a lack of proven techniques for artificially regenerating mixed species stands, or for adverse sites subject to growing season or permanent flooding. Thus**, <u>better information on the reproductive, seed, and regeneration biology of bottomland hardwood species is required to improve our understanding of natural and artificial regeneration processes and the application of successful regeneration methods.</u> (Problem 1)** Research will build on results from past studies to synthesize predictive models for assessing regeneration adequacy following regeneration harvests, including methods for assessing the contribution to the regeneration pool of advance seedling regeneration, stump sprouts, and new germinants. New studies will examine the biology of flowering, fruiting, and development of mast crops, in response to weather and biotic factors. The RWU will continue to lead in development of innovative imaging techniques for examining seed anatomy and physiology, directed at the problem of storing recalcitrant seed without loss of viability.

The utilization and value of hardwoods in general in the thirteen state southern region have increased as the demand for hardwood lumber and pulpwood went up since the early 1990s. Recent controversy over the proliferation of chip mills in the region has centered in the hardwood growing areas of the South. Our own agency predicts nearly 80 percent increase in harvesting of hardwoods in the next 50 years. In response to this increased demand on the southern bottomland hardwood resource, **<u>managers need sufficient information to develop silvicultural systems, predict stand development, and manage pest problems needed to maintain forest health and sustainably manage bottomland hardwood and wetland forests to provide desired commodity and non-commodity benefits.</u> (Problem 2).** Existing research and development efforts will serve as a strong base from which needed knowledge will be

synthesized and from which new efforts will begin. Long-term studies of silvicultural systems and tree growth in oak-sweetgum stands will continue and will be expanded to additional stands. Techniques for detecting pathogens that reduce end-product value will be developed for use in standing trees and in the absence of visible indicators of disease. New studies will begin to examine ways to control non-native invasive weed species and to better understand insect-pathogen interactions in bottomland hardwood forests.

Intact riparian systems, whether bottomland or upland, are facing increasing pressure from a growing diversity of human needs and expectations from the region's forests. Concomitantly, many endemic and sensitive aquatic and terrestrial species, particularly warmwater fishes, freshwater mussels, and Neotropical migratory birds, are dependent on these habitats to complete critical aspects of their life histories. Consequences of the loss and fragmentation of bottomland and riparian forests to the integrity of these communities has become a major concern of the public. Defenders of Wildlife identified southern-forested wetlands as one of the twenty-one most endangered ecosystems in the United States. The Partners in Flight planning process has identified bottomland systems across the South as the highest priority habitats for maintenance of breeding populations of Neotropical migratory birds as well as staging habitats for these birds during migration. The Cerulean Warbler is repeatedly identified as one of the highest priority species. In separate assessments, the Nature Conservancy and Defenders of Wildlife identified the South as having high to extreme risk for significant loss of aquatic biodiversity. These groups and the World Wildlife Fund regard sustained conservation actions in the region as vital to maintaining a significant proportion of the freshwater fauna of the United States with emphasis on native fishes, freshwater mussels, and crayfishes. Research approaches to management of forest ecosystems usually treat these nongame animals, whether aquatic or terrestrial, as constraints on or by-products of the management process. However, forest birds, warmwater fish communities, and freshwater mussels are all indicators of ecosystem quality and integrity. Hence, **sustainable management of riparian and bottomland hardwood ecosystems is impeded by the lack of information on the biology and ecology of aquatic and terrestrial animals, especially warmwater fishes, freshwater mussels, and Neotropical migratory birds. (Problem 3)** The RWU will continue to lead and conduct ecological research on warmwater fishes and freshwater mussels in forested watersheds and birds in bottomland hardwood forests. The RWU also will continue to lead aquatic ecological research for the Ouachita Ecosystem Management Research project. Research will advance conservation of these animals by increasing our understanding of their response to biotic and abiotic factors in riparian and bottomland systems, their ecological interrelationships, their habitat requirements, and their population dynamics. The research will provide resource managers with expected ranges in natural variability for animal community metrics. Management effects (beneficial or negative) cannot be measured accurately if background variability is unknown. Efforts at conservation could be futile or wasted if management actions are confounded with natural variability. The research will also provide forest managers with tested, standardized techniques to monitor population trends and habitat quality. The ultimate outcome is to provide information for better, scientifically-based management and recovery of warmwater fishes, freshwater mussels, and Neotropical migratory birds.

Increased utilization of bottomland hardwood forests places even greater stress on these endangered ecosystems. Although we have a conceptual understanding of the functioning of these ecosystems, our present knowledge is fragmented and lacks the detail necessary to manage them on an ecosystem basis. Hydrology is the driving force in these systems, yet much more is known about the effects of disturbance on relatively simple upland forest systems. Forested wetlands are critical sinks for excess nutrients and sediment, thereby maintaining water quality. Bottomland hardwood and wetland forests contribute to the

important role of floodplains in regional hydrologic cycles. Due to their characteristically high net primary productivity, bottomland hardwood and wetland forests support a diverse biota, including threatened, endangered, or sensitive plant species. Alterations of hydrologic patterns stress the energy signature of these ecosystems and impede recovery of ecological processes and restoration of wetland functions. Increased utilization of these systems requires a quantitative understanding of the dominant physical, chemical, and biological processes that define specific bottomland hardwood and wetland forest types. Such understanding will also facilitate development of techniques for restoring these ecosystems on former agricultural land. Thus, **a <u>better understanding of ecological processes and wetland functions is needed in order to sustainably manage, rehabilitate, and restore bottomland hardwood and wetland forests, and associated riparian and aquatic ecosystems.</u> (Problem 4)** Integrated research will continue in order to understand ecological processes, assess the impacts of forest management practices on these processes, and specify methods to recapture the functions and values of bottomland hardwood and associated aquatic ecosystems for degraded systems. This effort requires the establishment of baseline values for important processes and functions within relatively undisturbed bottomland hardwood ecosystems. Another emphasis of the research program is to quantify the effects, if any, of silvicultural practices on these same processes and functions. A third emphasis is methods to restore animal and plant communities and assess how well restored systems compare with target natural systems. The long-term goal of this research program is to develop environmentally sound forest management practices that simultaneously produce commodities and maintain or improve ecological values, and rehabilitate or restore degraded systems.

10. Approach to Problem Solution

<u>Problem 1. Better information on the reproductive, seed, and regeneration biology of bottomland hardwood species is required to improve our understanding of natural and artificial regeneration processes and the application of successful regeneration methods.</u>

Research in the last decade has established the recalcitrant nature of the seeds of many prominent forest tree species and our inability, as managers, to predict the longevity of these seeds in seed banks and the species composition resulting from such natural regeneration. Publications and presentations by the team on these findings have been numerous, and include information on such topics as (1) the physiological, biochemical, and ultrastructural effects of desiccation on recalcitrant tree seeds and their relationship to loss of seed viability; (2) the efficacy of imaging techniques as seed viability predictors; (3) the effects of overstory and flooding regimes on natural and artificial hardwood regeneration. However, much remains to be done. The storage recalcitrant tree seed is an as yet insurmountable problem. Scientists working on this problem are now focusing on the carbohydrates and over-all physiology of recalcitrant seeds and on innovative MRI and CT imaging techniques to examine both seed anatomy and physiology. In addition, regeneration experiments already in place will be supplemented by studies examining the ecophysiological requirements of seedlings under varying light and moisture regimes and the effects of preharvest treatments on natural regeneration processes. A revision of Agricultural Handbook No. 450 (Woody Plant Seed Manual) and a new Tropical Tree Seed Manual are underway.

<u>Element 1.</u> Methods to predict the effect of regeneration treatments on species composition and stand structure, with emphasis on establishment of oaks and other preferred bottomland hardwood species are lacking.

<u>Topic 1.</u> Methods are needed to enable prediction of post-harvest regeneration prior to the

regeneration cut in bottomland hardwood stands with complex species associations. Studies of natural regeneration processes under various site types and stand conditions are needed to expand and modify current regeneration prediction models.

Study 1. Natural regeneration of hardwoods in major and minor river bottoms

Study 2. Effect of pre-harvest treatments on natural regeneration processes

Topic 2. The ecological and physiological factors controlling establishment, survival, and growth of hardwood regeneration are not well understood. Studies of how seedling physiology is influenced by environmental factors such as light and soil moisture are needed to understand the basic biological requirements of survival and growth of bottomland hardwood regeneration.

Study 1. Water relations and morphology of Nuttall oak seedling sprouts

Study 2. Response to extended flooding by Nuttall oak and cherrybark oak seedlings grown under two light regimes

Study 3. Bottomland oak seedling establishment and growth along a topographical gradient

Study 4. Effect of soil moisture availability by site on seedling water relations

Topic 3. Studies are needed to examine the benefits of silvicultural practices on the establishment and growth of bottomland hardwood regeneration. Investigations should lead to new technologies for reliable and cost effective establishment of bottomland hardwood regeneration.

Study 1. Development of coppice regeneration in water oak plantation subjected to two thinning intensities

Study 2. Partial cutting to facilitate establishment of artificial Nuttall oak regeneration in the Mississippi Delta

Study 3. Methods to improve establishment and growth of bottomland hardwood artificial regeneration

Study 4. Physiology, morphology, and growth of Nuttall oak artificial regeneration beneath an Eastern cottonwood nurse crop

Study 5. Influence of seedling quality on establishment success and growth of bottomland hardwood species

Study 6. Midstory control for establishment of oak regeneration

Study 7. Underplanting beneath a partial overstory to establish cherrybark oak regeneration in a minor bottom of southwestern Arkansas

Element 2. The reproductive biology of key hardwood species is poorly understood. The relationships

between shoot physiology and growth, flower and seed production and quality, and nutrient cycling in some key bottomland hardwood species have not been explored.

Topic 1. Studies examining carbon allocation, flowering, pollination, seed production, and germination ecology of key over-, mid-, and understory species in bottomland hardwood stands, and the effects of climate on these factors, need to be initiated.

Study 1. Carbon allocation, shoot growth, and the reproductive biology of bottomland oaks

Study 2. A thermogradient study of the germination requirements of midstory and understory bottomland hardwood species

Element 3. The storage physiology of key hardwood species is poorly understood. There are serious problems in storing the recalcitrant, or desiccation-sensitive, seeds of some tree species, most notably the oaks.

Topic 1. Investigations on obtaining and maintaining seed quality in selected species, and on new technologies to enhance and maintain this quality, need to be established. Studies using new and established technologies are needed to examine the biological, biochemical, and anatomical changes brought about by (a) desiccation, (b) chilling, (c) term of storage, and (d) combinations of these factors. Experiment using gas chromatography, accelerated aging, and differential scanning calorimetry in concert with the advanced technologies of magnetic resonance imaging and nuclear magnetic imaging can offer new insights into seed recalcitrance and basic seed biology.

Study 1. An FTIR study of the embryo and cotyledon tissue of *Quercus alba* L. and *Quercus nigra* L.

Study 2. A comparative study of the fatty acids of artificially aged and naturally dehydrated *Quercus nigra* and *Fraxinus pennsylvanica* seeds

Study 3. Ultrastructural changes in desiccating seed

Study 4. Chromosome damage in stored seed

Study 5. Effects of desiccation on the carbohydrates of *Quercus alba* acorns

Problem 2. Forest managers lack sufficient information to develop silvicultural systems, predict stand development, and manage pest problems needed to maintain forest health and sustainably manage bottomland hardwoods and wetland forests to provide desired commodity and non-commodity benefits.

Over the last five years, research was done to develop practical guidelines to enable forest managers and landowners to more effectively grow and manage bottomland hardwoods. Most of the knowledge gained has been published or presented in many forms and includes information about: the relationship between crown areas of open-grown trees and site stocking; deferment cutting and thinning in bottomland stands; the causes and development of decline diseases in hardwoods; bacterial wetwood in red oaks; and

managing pests of ash and oak species. The team of scientists working on this problem will continue to provide the leadership to develop competent silvicultural and pest management guidelines to enable sustainable use of southern bottomland hardwood and wetland forests. New efforts will include studying the biology of exotic pests in bottomland hardwoods and developing control methods, and developing practical ways to detect and minimize pest-caused defects in standing trees.

Element 1. Forest managers need effective silvicultural guidelines and the quantitative tools to predict stand development to sustainably manage existing bottomland hardwood and wetlands forests.

Topic 1. Forest managers need information and quantitative tools to predict the development of stands over time and in response to silvicultural practices.

Study 1. Empirical yield information for bottomland hardwoods

Study 2. Growth and yield models for plantations of southern bottomland hardwoods

Study 3. Multiple silvicultural pathways in Delta bottomland hardwood forests

Topic 2. Forest managers need environmentally sound silvicultural practices that improve growth and quality of individual trees and stands beyond the sapling stage.

Study 1. Seed tree vs. selection in bottomland hardwoods

Study 2. Treatments to favor oak in mixed stands of hardwood regeneration

Study 3. Water oak plantation thinning

Study 4. Growth and quality development of residual trees following deferment cutting in red oak-sweetgum

Study 5. Release of suppressed cherrybark oak and green ash

Study 6. Thinning red oak-sweetgum stands on minor stream bottom sites

Element 2. Forest managers lack enough information about pest problems needed to manage healthy sustainable bottomland hardwood and wetland forests.

Topic 1. Forest managers need guidelines to minimize the effects of wood decay fungi, wetwood bacteria, herbivorous insects, and biotic and abiotic decline factors, as well as more information about the interaction between silvicultural practices and insect and pathogen populations.

Study 1. Identifying influential factors of oak decline in bottomland hardwood forests

Study 2. Infection and colonization of the roots of mature oaks by *Armillaria tabescens* three years after a severe ice storm

Study 3. The effects of stand modification on insect and disease communities in the lower Mississippi River ecosystem

Study 4. Phenological surveys of Wood borers (Coleoptera: Cerambycidae, Buprestidae) using malaise traps in bottomland hardwoods and other habitats in Mississippi

Topic 2. Managers of plantation hardwoods need information about the biology of insects and diseases in order to minimize losses.

Study 1. Genetic characterization of cottonwood leaf beetle populations

Study 2. Cerambycid beetle population studies

Topic 3. Managers of bottomland hardwood forests need economical and practical techniques to detect and control defects caused by insects and diseases in standing trees.

Study 1. Use of aromascan detector for the identification and discrimination of pathogenic bacteria and wood decay fungi in standing timber

Study 2. Use of ultrasound to detect wetwood

Topic 4. Managers need biological information to identify and control exotic pests.

Study 1. Wood wasps: vectors of wood decay fungi

Study 2. Classical biological control of exotic weeds in the southeast region

Problem 3. Sustainable management of riparian and bottomland hardwood ecosystems is impeded by the lack of information on biology and ecology of aquatic and terrestrial animals, especially warmwater fishes, freshwater mussels, and Neotropical migratory birds.

Over the last five years, team researchers provided critical information to natural resource managers on warmwater fishes, freshwater mussels, Neotropical migratory birds, and other terrestrial animals with emphasis on sensitive species. Most of this information is published or was presented in technology transfer efforts. Research on warmwater fishes emphasized: the national and regional distribution and conservation status of native fishes; associations of landscape history and attributes with fish diversity and imperilment; the biology and habitat of sensitive fishes; and initial studies of fish dispersal and long-term variability in fish communities. Freshwater mussel research produced work that provided a better understanding of: national imperilment of freshwater mussels; distribution and status of mussel species on national forests; habitat, host-fishes, and other life history requirements of sensitive mussel species; and the interaction of reproductive strategies and host-fish densities on the structure of freshwater mussel communities. Research on Neotropical migratory birds and other nongame bird species resulted in: development and standardization of sampling techniques for nongame birds; extensive data bases on the biology of the Cerulean Warbler and other Neotropical migratory birds of bottomland hardwoods; and initiation of studies of wildlife responses to forest restoration on abandoned agricultural lands.

Future research will address three broad areas of common information needs for management of aquatic

and terrestrial animals. Common areas of information need include monitoring tools, alternatives for habitat improvement and population recovery, and effects of large-scale processes on local populations. Future research on migratory birds will focus on (1) developing and validating monitoring protocols for migratory bird use of habitats in the winter; (2) evaluating responses of Neotropical migratory birds, particularly Cerulean Warblers, to techniques of forest harvest designed to improve habitat conditions for them; and (3) understanding the effects of large-scale processes on local populations of Neotropical migratory birds, particularly Cerulean Warblers, by comparing population responses of birds in different parts of their range. For warmwater fishes, efforts will be directed toward: (1) measuring fish response to restoration of a channelized river; (2) developing an index of biotic integrity for low gradient upper Coastal plain streams; (3) quantifying watershed-scale effects of timber management on fish and macroinvertebrate communities in the Interior Highlands; (4) quantifying warmwater fish community dynamics as functions of environmental variability and dispersal; and (5) assessing the distribution and conservation status of fishes in the Southern Region. Future research on freshwater mussels will focus on: (1) developing and validating monitoring and inventory methods; (2) assessing natural colonization success of mussels in a restored bottomland river; (3) determining the influence of host-fishes, habitat, and life history stages on population dynamics and assemblage composition of mussels.

To address these areas, the team will need to conduct foundational research on: community habitat relationships and species habitat requirements; patterns of movement, dispersal, and migration; and implications of life history traits for management actions. For the aquatic fauna, the team anticipates a continued research emphasis on sensitive warmwater fishes and mussels, and for the terrestrial community, efforts will be directed primarily toward Neotropical migratory birds, primarily the indicator species Cerulean Warbler. The intent of the team of scientists working under this problem is to provide information that allows treatment of these species as products of management rather than constraints to or by-products of management.

Element 1. Linking forest management activities to stream fishes requires an understanding of the variability of fish communities and their response to biotic and abiotic factors operating across space and time. Management for diverse, functioning fish communities also requires understanding those features of life history, reproductive biology, and dispersal of individual species that are simultaneously critical to the animal and sensitive to management.

Topic 1. Managers lack tested management alternative affecting the recovery of fish communities and sensitive fish species and lack region-specific monitoring tools for determining fish community response to watershed management.

Study 1. Fish and mussel community response to restoration of a channelized bottomland river (Little Tallahatchie River, Mississippi)

Study 2. Development of an Index of Biotic Integrity for fish communities of forested watersheds in the upper Coastal Plain (Mississippi National Forests)

Topic 2. Managers need information on the effects of landscape-scale processes and historical events on the distribution and abundance of warmwater stream fishes.

Study 1. Large-scale effects of timber harvesting on regional fish and macroinvertebrate assemblages in the Ouachita Mountains, Arkansas (Ouachita National Forest)

Study 2. Environmental variability, historical contingency, and the structure of regional fish and macroinvertebrate assemblages in Ouachita Mountain stream system (Ouachita National Forest)

Topic 3. Managers lack up-to-date information on the distribution, abundance, and status of warmwater stream fishes, especially sensitive species.

Study 1. GIS-compatible fish research database for the Ouachita and Ozark Mountain drainages (Ouachita and Ozark National Forests)

Study 2. Diversity, distribution, and status of fishes of the southern United States

Topic 4. Managers need a better understanding of community habitat interrelationships and species habitat requirements for warmwater fishes to predict effects of management actions.

Study 1. Microhabitat interrelationships of stream fishes inhabiting severely to moderately incised channels of upper Coastal Plain streams in Mississippi

Study 2. Autecology and recovery of the federally endangered palezone shiner (Cyprinidae) in the Little South Fork, Kentucky, with emphasis on fish community structure, habitat relationships, and restoration (Daniel Boone National Forest)

Study 3. Fish and macroinvertebrate communities and habitat stability under different ecosystem management regimes (Ouachita National Forest)

Study 4. Trophic relationships of fishes of the Ouachita Mountains, (Ouachita National Forest)

Topic 5. Managers lack information on movement patterns, dispersal, and migration of warmwater fishes.

Study 1. Home ranges, daily movement and effects of habitat isolation on dispersal of small-stream warmwater fishes in Ouachita Mountain streams (Ouachita National Forest)

Study 2. Predicting dynamics imposed by migration in warmwater stream-fish assemblages (Ouachita National Forest)

Element 2. Maintenance, enhancement, and recovery of freshwater mussel communities require an understanding of responses to abiotic and biotic factors operating across space and time. Management of freshwater mussels also requires understanding the life history, fish-host relationships, reproductive biology, and habitat requirements of these animals.

Topic 1. Managers lack validated sampling and monitoring protocols for sensitive mussels.

Study 1. Comparison of the efficiencies of visual searches and substrate excavations in inventory and monitoring of freshwater mussel communities (Ouachita and Alabama

National Forests)

Study 2. Development of a standardized methodology for inventory and monitoring of freshwater mussel communities on national forests

Topic 2. Managers lack tested alternatives for effecting the recovery of mussel communities and sensitive species.

Study 1. Fish and mussel community response to restoration of a channelized river bottom

Topic 3. Managers need information on community habitat relationships, species habitat requirements, distribution, abundance, and critical life history stages of freshwater mussels to predict effects of management actions.

Study 1. Diel patterns of mantel display, influence of fish presence and photoperiod on release of freshwater mussel larvae, and geographic variation in fish-hosts among sensitive species of synoptic freshwater mussels (Bankhead and Talladega National Forests, Alabama; Chattahoochee National Forest, Georgia)

Study 2. Reproductive periodicity of four threatened and endangered mussels in Mobile Basin

Study 3. Determination of fish-hosts for *P. decisum*, a federally listed mussel species, three sensitive species, and two currently stable species in the Mobile Basin

Study 4. Use of historical and recent survey information to evaluate changes in freshwater mussel communities in the Little South Fork Cumberland River (Daniel Boone National Forest, Kentucky)

Study 5. Demographics and population dynamics of freshwater mussels in forested and non-forested landscapes

Element 3. Effects of land management and forest fragmentation on the distribution and abundance of terrestrial animals, particularly forest canopy inhabiting Neotropical migratory birds such as Cerulean Warbler, in bottomland hardwood and wetland forests are poorly understood. Sustainable multiple-resource management requires dependable production of populations of forest wildlife, for example, canopy inhabiting Neotropical migratory birds and threatened, endangered or sensitive species of birds and other faunal groups. Current understanding of these species is insufficient to prescribe management actions that will produce specified population levels of these animals, especially for inhabitants of later successional stages like Cerulean Warbler.

Topic 1. Managers lack validated monitoring protocols and quantitative indices for evaluating effects of forest management on Neotropical migratory birds.

Study 1. Wildlife use of bottomland hardwoods fifty years after timber stand improvement or clear cutting: I. Density and species composition of the breeding and wintering avifauna

Topic 2. Managers need tested, alternative silvicultural prescriptions for production of habitats for Neotropical migratory birds.

Study 1. Differential response of Cerulean Warbler populations to logging and ice-storm occurrence in a tract of bottomland hardwood forest in Desha County, AR

Study 2. Distribution of Winter Wrens in relation to dispersal of logging debris in harvesting of bottomland hardwood stands

Topic 3. Managers need information on effects of landscape-scale processes and historical events on the distribution and abundance of Neotropical migratory birds.

Study 1. A quantitative assessment of bird community composition and dynamics for reference sites involved in study of structure and functions of forested wetlands in bottomland hardwood ecosystems in the southern United States

Study 2. Intermediate scale distribution of Cerulean Warblers

Study 3. Prediction of distribution of Cerulean Warblers among bottomland tracts using percolation theory

Study 4. Long-term effects of post-Columbian depopulation of the Mississippi Alluvial Valley on distribution of sensitive Neotropical migratory bird species

Topic 4. Managers lack up-to-date information on the distribution, abundance, and status of terrestrial animals, particularly Neotropical migratory birds, and sensitive to forest management activities in bottomland hardwood forests of the Mississippi Alluvial Valley.

Study 1. Status assessment of the Cerulean Warbler

Topic 5. Managers lack information on habitat relationships of communities and habitat requirements of sensitive species of terrestrial animals in bottomland hardwood forests.

Study 1. Nearest neighbor analysis of canopy-dwelling warbler species in bottomland hardwood forests

Study 2. Prediction of use of trees for nesting substrate by Cerulean Warblers, shade tolerance versus relative abundance in the plant community

Study 3. Characteristics of territories of Cerulean Warblers in bottomland hardwood tracts of the Mississippi Alluvial Valley

Study 4. Three-dimensional distribution of foliage in Cerulean Warbler habitats in the Mississippi Alluvial Valley

Topic 6. Managers lack information on relationships of abundance estimates to measures of productivity and survival of species.

Study 1. Productivity and abundance of forest birds breeding in bottomland hardwood forests of the Mississippi Alluvial Valley

Study 2. Cerulean Warbler populations in bottomland hardwood forests, distribution, abundance, and productivity

Study 3. Comparison of long-term annual variation with large-scale spatial variation in winter bird communities of mature bottomland hardwood forests of the Mississippi Alluvial Valley

Problem 4. Better understanding of ecological processes and wetland functions is needed in order to sustainably manage, rehabilitate, and restore bottomland hardwood and wetland forests, and associated riparian and aquatic ecosystems. Over the last five years, the RWU has been a leader in developing multiagency, interdisciplinary studies of ecosystem function and restoration. Long-term research efforts at the Iatt Creek Ecosystem Research and Management Site and the Sharkey Restoration Site will continue. These efforts will be expanded to include new areas of research and to additional community types. Within the framework of the Southern Research Station Cross-Cutting Themes, research on soil quality response to restoration treatments will be expanded to other ecosystems. Techniques for integrated watershed restoration will be developed, including restoration of fish communities and aquatic ecosystems, in conjunction with restoration of riverine forest communities, and restoration of federally endangered plants such as pondberry (*Lindera melissifolia*).

Element 1. Ecological processes in bottomland hardwood forests are poorly understood. Natural disturbance regimes at the level of stand or landscape affect community composition and biodiversity but hydroperiod drives productivity. Biological productivity and nutrient cycling processes within bottomland hardwood systems are intimately linked. Both the processes and their linkages within the bottomland, and to adjacent upland or aquatic systems, are poorly understood. Above- and belowground net primary productivity and nutrient transfers are of critical importance to nutrition and growth yet have been scantily studied. Similarly, internal plant nutrient cycles and bottomland detritus pathways have only been studied in a rudimentary fashion. The potential storage of carbon in biotic and abiotic components of wetland ecosystems are potentially large, in both dynamic and stable storage pools.

Topic 1. Studies are needed to develop a better understanding of the natural disturbance regimes in bottomland hardwood forests and the dynamics of stand replacement and canopy development.

Study 1. Gap disturbance mechanisms, recurrence intervals, and vegetation response in relatively undisturbed major and minor bottom stands

Study 2. Effects of natural and human-induced disturbances on composition and diversity of forest communities across the landscape

Study 3. Parameterize a process model (PnETII) of canopy function

Study 4. Dendrochronology of cypress and other coastal wetland forests

Topic 2. Studies are needed to develop a quantitative understanding of net primary

productivity of various forested wetland community types, which are linked to process models of nutrient dynamics.

Study 1. Net primary productivity of reference (relatively undisturbed) stands

Study 2. Belowground productivity in natural and plantation stands

Study 3. Nutrient cycling in natural and plantation stands

Study 4. Dynamics of coarse and fine woody debris

Topic 3. Sustainable forest management requires conservation of biodiversity but techniques to maintain diversity and threatened, endangered, or threatened plants in fragmented forest landscapes typical of bottomland hardwoods are lacking.

Study 1. Floristic diversity of managed and plantation forests

Study 2. Population dynamics, physiology, and restoration of the endangered pondberry (*Lindera melissifolia*)

Topic 4. A better understanding is needed of fluvial processes in forested wetlands, including linkages within floodplains and between bottomland hardwood forests and aquatic or upland systems.

Study 1. Hydroperiod influences on productivity

Study 2. Hydrologic linkages of bottomland communities with upland and aquatic systems

Study 3. Improved techniques for quantifying wetland hydrology

Study 4. Land use influences on fluvial processes

Element 2. As management of the bottomland hardwood resource intensifies, managers' need information on likely effects of management practices on sustainability of forests and associated aquatic ecosystems, as well as their need for techniques of sustainable management.

Topic 1. Best Management Practices (BMP), particularly streamside buffer zones (SMZ), appear to be effective management tools for reducing or avoiding impacts on water quality from forest management. The scientific basis for SMZ design in the South is sparse. Managers need information on the efficacy of SMZ in protecting water quality.

Study 1. Buffer zone efficacy

Study 2. Forested buffer strips to protect water quality in intensive agricultural landscapes

Study 3. Rational design methods for specifying SMZ widths and management

Topic 2. As management of existing stands intensifies in order to meet greater demand for fiber on a shrinking land base, managers' needs for information on potential effects of intensive management of bottomland hardwood and wetland forests will increase.

Study 1. Effects of short rotation woody crops

Study 2. Assessing effects of management on net primary productivity and carbon sequestration

Element 3. Restoration of bottomland hardwood systems must be viewed as a continuous process. Those techniques currently being used for restoration revolve around establishing a hard mast species, usually oaks, on abandoned agricultural fields. There is also a push to examine economically viable ways of restoring lands that have been heavily degraded. Techniques used include appropriate species selection, site preparation, quality control and maintenance. Adaptive management is leading us to examine alternative forest restoration methods, which may include the use of nurse crops or the introduction of herbaceous species.

Topic 1. Managers need techniques for restoring stand structure, including vertical structure and species diversity, for mimicking soil processes, and for maintaining animal communities.

Study 1. Large-scale comparison of restoration techniques for bottomland hardwoods on former agricultural land

Study 2. Techniques to increase survival of planted and direct-seeded bottomland hardwood overstory species

Study 3. Establishment of intimate mixtures of multiple species

Study 4. Techniques for rapidly restoring vertical structure using nurse crops

Study 5. Restoration of herbaceous, understory, and midstory species on former agricultural land

Study 6. Response of small mammal populations to restoration of forest to abandoned agricultural lands on the Sharkey Site, Sharkey County, MS

Study 7. Winter raptor populations and predation on small mammal populations in relation to restoration of forest to agricultural lands on the Sharkey Site, Sharkey County, MS

Study 8. Assessment of techniques to determine population levels of avifauna wintering in restored forests on the Sharkey Site, Sharkey County, MS

Topic 2. Managers need techniques for restoring hydroperiod, river flows and aquatic communities in hydrologically altered systems.

Study 1. Restoring hydrology on Wetlands Reserve Program sites

Study 2. Land use influences on fluvial processes

Study 3. River restoration techniques

Topic 3. Monitoring treatment results is a prerequisite for sustainable management. Managers need cost-effective monitoring and evaluation procedures for assessing restoration success.

Study 1. Survey techniques for monitoring restoration success

Study 2. Assessing soil quality restoration

Study 3. Bioindicators of functional restoration

Study 4. Application of the Index of Biological Integrity to bottomland aquatic communities

Study 5. Development of criteria and indicators of sustainable forest management applicable to bottomland hardwood and wetland forests

Technology Transfer and Development Activity

In 1960, Putnam and co-workers published Agriculture Handbook 181, Management and Inventory of Southern Hardwoods. While still widely used by practitioners, Ag Handbook 181 badly needs revision in incorporate research results obtained over the last 40 years. Our plan for technology transfer includes expanding and updating Ag Handbook 181, including chapters on natural and artificial regeneration; growth and yield of natural and plantation stands, including application of stand density management; wildlife management; intermediate stand culture; ecology of bottomland hardwood and wetland forests; protection of aquatic resources and water quality; and forest health.

We will continue to present current research results at meetings, short courses, field trips, and workshops. Specific technology transfer efforts include a one-day meeting every February, sponsored by the Southern Hardwood Forest Research Group. The meeting is open to everyone and attendance typically runs between 75 and 125 people. Scientists present results of on-going work, in rotation. Other technology transfer activities will include formal training programs, such as a short course for wildlife managers on a protocol for point count census of neotropical migratory avifauna; the Tree Seed Short Course for seed technologists; short courses through Mississippi State University on bottomland hardwood regeneration and on stand management; Aquatic Monitoring for Natural Resource Specialists short course through the FS/BLM National Aquatic Monitoring Center; and participation in short courses and training workshops sponsored by other organizations. Informal training occurs on a regular basis.

The great need for technical assistance to agencies and landowners afforesting bottomland hardwoods under the Wetlands Reserve Program has been recognized by federal agencies. For three years, several agencies (State and Private Forestry, Environmental Protection Agency, Fish and Wildlife Service, and Natural Resources Conservation Service) contributed salary support for a technology transfer specialist at the Center. The individual, a Ph.D. in hardwood silviculture, maintained an applied research program in artificial regeneration, as well as an active technology transfer/technical assistance effort. We hope to replace this person.

Dissemination of research results to multiple audiences requires multiple outlets. The most recent findings will be presented in short courses and seminars; research papers; color-illustrated guides; and CD ROMs. We anticipate greater utilization of Inter- and Intranet technology for disseminating our research. This already occurs to some extent, for example through the SRS webpage, current publications can be downloaded and printed in pdf format. We plan to make selected older publications available as they can be scanned and edited. Other on-line applications are planned, such as interim growth and yield models.

Several studies now underway could lead to developing products. The work on ultrasound detection of wetwood in standing trees, for example, is being pursued toward establishing a CRADA to develop a device suitable for field use. Other development products in preparation include a decision support system for matching species to site in restoration/afforestation efforts, and a GIS database of conservation status of fishes in southern rivers.

Conservation Education

Preliminary efforts to develop a local consortium for conservation education among federal and state natural resource agencies will continue. We typically provide about 25 programs annually for schools and youth organizations. We seek outside funding to hire a conservation educator and to remodel a shop building into a natural resources education center.

Environmental Considerations

Most of the research is included under a categorical exclusion. Where studies are conducted in natural areas or other preserves, all agency regulations and guidelines are followed. Specific environmental issues are addressed in individual study plans or in Environmental Assessments prepared by federal agency cooperators. For example, our work at Iatt Creek on the Kisatchie National Forest is covered by several EIAs. All relevant federal regulations are followed in collecting animals and working with endangered plants. Several staff have been granted certified pesticide applicator status and maintain their certification. Relevant OHSA and EPA regulations are followed for handling and storage of chemicals, and for meeting right-to-know in the workplace regulations.

Quality Assurance/Quality Control

The Center for Bottomland Hardwoods staff fully complies with the Quality Assurance Plan of the Southern Research Station. This strategy places primary emphasis for QA/QC on the process for developing, reviewing, and approving study plans and secondary emphasis on the manuscript review and approval process, which includes appropriate biometrics review. In addition, we have a QA/QC plan specific to the operation of the Soils, Tissue, and Water Laboratory at the Southern Hardwoods Lab in Stoneville.

Current Staffing

The scientific staff consists of sixteen permanent full-time scientists, including the Project Leader. There currently are 12 permanent and 1 temporary full-time technicians, a chemist and two laboratory technicians, a computer specialist; four full-time and one part-time administrative staff; and ten Older American positions with the RWU (Table 1). Summer student and international volunteer staffing averages 8 to 10 annually.

Table 1. Current Staffing

Problem Number/Title	SY	Scientists
1-Regeneration & Reproductive Biology	3	Connor, Team Leader; Vozzo, Gardiner
2-Stand Development & Forest Health	5.0	Leininger,Team Leader; Meadows, Goelz, Wilson, Schiff
3-Terrestrial and Aquatic Fauna	4.0	Warren,Team Leader; Hamel, vice-Johnston, new-malacologist
4-Ecological Processes and Restoration	3.5	Devall,Team Leader; Stanturf (Project Leader), Meier, vice-Marion

Staffing Needs

The staffing strategy for the RWU calls for a core staff of 16 PFT scientists which can expand by the addition of post-doctoral or term scientists as needs arise and funding allows. A long-term growth strategy has been developed, in which core staff can grow to 20 PFT scientists. Conduct of this research requires 16.0 PFT scientists in Year 1 (FY 2000), with an annual cost of $3.35 million at the RWU allocation level appropriated funding, based on FY 2000 president's Budget. Current staffing by problem is shown in Table 1. The number of scientists could grow to 18.0 PFT (Table 2) for the remaining years of the RWUD (FY 2001 to FY 2004) at an annual cost of $4.050 million (Table 3). This will be supplemented by an average of $200,000 per year in grants and contracts, and an average of 1 to 3 SY equivalents from post-doctoral scientists and students supported under cooperative research agreements. The level of permanent staff is broken down by problem in the following table. As can be seen, there are three vacancies at the time of this writing (aquatic ecologist; fisheries biologist/malacologist; hydrologist).

Table 2. Permanent Staffing Projection

Problem Number /Title	FY 1	FY 2	FY 3	FY 4	FY 5
1-Regeneraton and Reproductive Biology	3.5	4.0	4.0	4.0	4.0
2-Stand Development and Forest Health	5.0	5.0	5.0	5.0	5.0
3-Terrestrial and Aquatic Fauna	4.0	4.0	4.0	4.0	4.0
Ecological Processes and Restoration	3.5	5.0	5.0	5.0	5.0
TOTALS	16.0	18.0	18.0	18.0	18.0

--Progress in achieving results under Problems 1 and 4 will be improved if an artificial regeneration specialist can be added to the project. Ideally, this person would replace the technology transfer specialist once funded by State and Private Forestry, Region 8. This addition is shown in Table 2

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--Progress in achieving results under Problem 4 will be improved if a community ecologist could be added to the project. This addition is shown in Table 2.

--The number of permanent technicians needs to be expanded by four to meet the minimal needs of current staff. The most efficient and productive configuration of scientists and technicians would require an

additional 8 technicians for the current staff, or 12 more technicians if two additional scientists are added. These costs are reflected in the budget for Years 2-5 (Table 3).

--Greater progress in technology transfer would result from addition of a technical writer/editor to the staff. Funding for this position will be sought from outside and is not reflected in the budget (Table 3).

--More opportunities for conservation education would be realized by addition of a conservation educator to the staff. Funding for this position will be sought from outside and is not reflected in the budget (Table 3).

Problem Number/Title	FY 1	FY 2	FY 3	FY 4	FY 5
1-Regeneration and Reproductive Biology	787.5	900.0	900.0	900.0	900.0
2-Stand Development and Forest Health	1,125.0	1,125.0	1,125.0	1,125.0	1,125.0
3-Terrestrial and Aquatic Fauna	900.0	900.0	900.0	900.0	900.0
Ecological Processes and Restoration	787.5	1,125.0	1,125.0	1,125.0	1,125.0
TOTALS	3,600.0	4,050.0	4,050.0	4,050.0	4,050.0

Table 4. Cooperators

Cooperators	
Foundations and Conservation Organizations	***Federal Agencies***
American Fisheries Society (National, Southern Division, and Miss. Chapter)	U.S. Army Corps of Engineers, Vicksburg District
American Society of Ichthyologists and Herpetologists	U.S. Army Corps of Engineers, Waterways Experiment Station
Conservation Fisheries, Inc., Knoxville, TN	Environmental Protection Agency Region IV
Delta Council	USDI Fish and Wildlife Service, Ecological Services, Region
Delta Research Foundation	USDI Fish and Wildlife Service, Alligator River NWR, NC
Delta Wildlife Foundation	USDI Fish and Wildlife Service, Chickasaw NWR, TN
FISHNET	USDI Fish and Wildlife Service, D'Arbonne NWR, LA
Hobart Ames Foundation	USDI Fish and Wildlife Service, Noxubee NWR, MS
International Union for the Conservation of Nature (IUCN)	USDI Fish and Wildlife Service, Tensas River NWR, AR
Kentucky Academy of Science	USDI Fish and Wildlife Service, White River NWR, AR
National Wild Turkey Federation	USDI Fish and Wildlife Service, Yazoo NWR Complex, MS
The Nature Conservancy (National and state)	USDI, Geological Survey, Water Resources Division
Ross Foundation, Arkadelphia, Arkansas	USDI, Geological Survey, Biological Resources Division
Southeastern Fishes Council	USDOE, Oak Ridge National Laboratory
Southern Hardwood Forest Research Group	USDOE, Savannah River Ecology Laboratory
Southern Hardwood Forestry Group	USDA, Agricultural Research Service
The Wildlife Society	USDA, Forest Service, Alabama National Forests
State and Local Agencies	USDA, Forest Service, Cherokee National Forest
Alabama Museum of Natural History	USDA, Forest Service, Daniel Boone National Forest
Arkansas Department of Game and Fish, Dave Donaldson WMA	USDA, Forest Service, Delta National Forest
Arkansas Department of Game and Fish, Hurricane Lake WMA	USDA, Forest Service, Kisatchie National Forest
City of Austin, TX, Forestry, Parks and Recreation Dept.	USDA, Forest Service, Mark Twain National Forest
Florida State Museum	USDA, Forest Service, Mississippi National Forests
Illinois Natural History Survey	USDA, Forest Service, Ouachita National
Kentucky Department of Fish and Wildlife Resources	
Kentucky Division of Water Quality	
Kentucky State Nature Preserves Commission	
Louisiana Department of Wildlife and Fisheries	
Mississippi Agriculture and Forest Experiment Station	
Mississippi Department of Fisheries,	

Cooperators	
Wildlife, and Parks Mississippi Museum of Natural Science Missouri Department of Conservation New York State Dept. of Health North Carolina Division of Forestry Oklahoma Biological Survey Pearl River Water Commission Tennessee Aquarium Tennessee Conservation League Tennessee Division of State Parks Tennessee Wildlife Resources Agency Texas Forest Service, Division, Lufkin, TX Texas Oak Wilt Suppression Project, Austin, TX Texas Water Board *International* Danish Forest and Landscape Research Institute, Ministry of Environment and Energy Forest Research Institute, Dehra Dun, India Instituto Nacional de Pesquisas da Amazônia, Manaus-AM, Brazil Institute of Ecology, Xalapa, Mexico Center for Tropical Coastal Management, University of Newcastle, UK	Forest USDA, Forest Service, Ozark National Forest USDA, Forest Service, Mussel Coordination Program (R8 NFs) USDA, Forest Service, Center for Aquatic Technology Transfer USDA, Forest Service, Fisheries, Wildlife, and Range (R8) USDA, Forest Service, National Aquatic Monitoring Center (NFS/BLM) USDA, Forest Service, State and Private Forestry (R8) USDA, Forest Service, Wildlife, Fish, and Rare Plants (WO-NFS) USDA, Natural Resources Conservation Service *Southern Research Station Research Work Units* Trout Productivity in Southern Appalachian Streams Integrated Management of Wildlife Habitat and Timber Resources Ecology and Management of Forested Wetland Ecosystems of the Southeastern Coastal Plain Primary Hardwood Processing and Products Forest Soil Productivity in the Southeast Biological/Engineering Systems and Technologies for Ecological Management Silviculture of Artificially Regenerated Southern Pines Multiresource Management of Naturally Regenerated Upland Forests in the Mid-South