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

4. Research Work Unit Title
Center for Bottomland Hardwoods Research

5. Project Leader (Name and Address)
Theodor D. Leininger, P.O. Box 227, Stoneville, MS 38776

| 6. Area of Research Applicability<br>Southern bottomland hardwoods, forested wetlands, riparian zones, and associated aquatic ecosystems, National, and International | 7. Estimated Duration<br>5 Years |
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8. Mission
To provide the scientific basis to manage southern bottomland hardwood and wetland forests and associated stream ecosystems for a sustained yield of forest products and other desired values.

9. Justification and Problem Selection
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. 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. Bottomland hardwood and wetland forests account for 15%, or 30 million acres, of the total forestlands in the southeastern United States (hereafter, the South). More than 90% of these forests are privately owned. Non-industrial private landowners account for 66%, while forest industry owns about 25%. Approximately half of the wetland resource in the U.S. occurs in the South, and the majority of these wetlands are forested.

| Signature | Title | Date |
|---|---|---|
| Recommended:<br>/s/ Nancy G. Herbert | Assistant Director for Research | Feb. 7, 2006 |
| /s/ Marilyn A. Buford | Assistant to Staff Director, VMPR (Lead Staff) | 21 Feb 2006 |
| /s/ Jimmy L. Reaves | Staff Director, VMPR (Lead Staff) | 2-21-06 |
| /s/ Thomas R. Crow | Assistant to Staff Director, ESR | 3/6/06 |
| /s/ Deanna J. Stouder | Staff Director, ESR | 7 Mar 06 |
| Approved:<br>/s/ Peter J. Roussopoulos | Station Director | 9 Mar 06 |
| Concurred<br>/s/ Jimmy L. Reave (for) | Deputy Chief for Research | 14 Mar 06 |

The forested wetland resource is an integral component of the commercial forest resource in the South, where high rates of timber and fiber biomass production are possible without compromising environmental values. Southern bottomland hardwood forests contain about 45 billion cubic feet of growing stock, of which 26 billion cubic feet (160 billion bd. ft International ¼ in. scale) are in sawtimber. The utilization and value of southern hardwoods in general have increased as the demand for hardwood lumber and pulpwood continues to rise. 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.

These bottomland hardwood forests provide critical benefits that are fundamental to ecosystem health at multiple scales. These forests 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 of the forests they support have been cut and the land converted to agricultural uses. In fact, from the early 1800's until the early 1980's, about 80% of the 24 million acres of bottomland hardwood forest in the Lower Mississippi Alluvial Valley (LMAV) underwent this conversion. Accordingly, the remaining bottomland hardwood forests are a critical economic and ecological resource. Currently, there is great interest from the Department, the Agency, various nongovernmental organizations, and to a degree, private landowners to reestablish forests on a greater portion of the LMAV. This restoration of forests by afforestation of agricultural land needs to be done strategically so as to reap the maximum ecological and economic benefits. Research needs to provide private and public decision makers with cost-effective, financially viable, and ecologically sound management systems.

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 techniques. Stands have deteriorated due to periodic diameter limit cutting; many stands are dominated by slow-growing, shade tolerant species of less value for wildlife or timber. There is especially a lack of regeneration by oaks, which as a group are the most ecologically and economically valuable component of these bottomland hardwood stands. Past research has established the recalcitrant nature of the seeds of many prominent bottomland hardwood forest tree species. Because of many unknowns related to the longevity of seeds in seed banks, managers cannot accurately predict species composition of stands resulting from natural regeneration, or be assured that the new 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**, managers need better information on reproductive, seed, and regeneration biology to successfully regenerate and restore bottomland hardwood forests. (Problem 1)**

In bottomland hardwood forests of the South, 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. The utilization and value of

hardwoods in the thirteen-state southern region continue to increase in accord with the increasing national and international demand for hardwood lumber and pulpwood. 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. In response to this increased demand on the southern bottomland hardwood resource, **forest managers need improved silvicultural systems and better information on growth and yield, stand development, and the management of insect and disease problems to provide a sustainable yield of desired multiple-use benefits from bottomland forests. (Problem 2)**

Streams and associated riparian ecosystems of the southern United States provide important habitats for the most diverse terrestrial and aquatic fauna on the continent. These areas are increasingly imperiled by pressure from a growing array of human needs and expectations from the region's forests. Forested watersheds in the South increasingly serve as the last refugia for many sensitive species of birds, nongame fishes, mussels, crayfishes and other riparian-dependent wildlife. Bottomland hardwood forests provide breeding or wintering habitat for 176 bird species; even larger numbers of Neotropical and northern migratory bird species use these forests as vital migratory habitat. About 28% of southern U.S. fishes are classified as endangered, threatened, or vulnerable; over 70% of native freshwater mussel taxa are imperiled; and 48% of southern crayfishes are endangered, threatened, or of special concern. 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.

Many endemic and sensitive aquatic and terrestrial species, particularly warmwater fishes, freshwater mussels, and migratory birds, are dependent on stream and riparian habitats to complete critical aspects of their life cycles. There is concern that additional loss and fragmentation of bottomland and riparian forests will further imperil the integrity of these communities. Defenders of Wildlife identified southern-forested wetlands as one of the 21 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 has been identified repeatedly as one of the highest priority species, is listed as Vulnerable by the International Union for the Conservation of Nature and Natural Resources, and is under petition for Federal listing as threatened. The Rusty Blackbird, an obligate winter resident of bottomland hardwood forests, has declined by 95% in the last three decades. The recently rediscovered Ivory-billed Woodpecker, long believed extinct, requires research and management attention. 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, most of which is associated with rivers and streams in the region. These groups 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. It is important that research approaches to management of forest ecosystems treat these nongame animals, whether aquatic or terrestrial, as integral components and critical ecological benefits of the management process. Forest birds, warmwater fish communities, crayfishes, and freshwater mussels are all indicators of ecosystem quality and

integrity. Thus, to manage stream, riparian, and bottomland hardwood ecosystems in a sustainable way, **land managers need a more comprehensive understanding of the biology and ecology of warmwater fishes, freshwater mussels, crayfishes, and Neotropical migratory and other birds. (Problem 3)**

Existing bottomland hardwood forests are under greater stress due to increased demand and utilization of these ecosystems. In addition, efforts are underway to restore bottomland hardwood forests on an increasing number of acres of economically marginal farmland in the lower Mississippi River Valley. The management of existing forested bottomlands and restoration of other bottomland hardwoods require an understanding of how these ecosystems function. Our present knowledge about these ecosystem functions is fragmented and lacks the detail necessary to manage 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.

Understanding the ecological processes would also facilitate efforts to restore bottomland hardwood ecosystems on former agricultural land. Between 500,000 acres and 1 million acres of economically marginal farmland in the lower Mississippi River Valley were planted in forest trees in the past fifteen years. More effective restoration techniques are needed by public and private land managers to successfully recapture wetland functions lost when these lands were converted to agricultural use. Techniques are needed: for restoring mixed species stands, including understory and midstory species; for establishing and maintaining populations of rare and endangered flora and fauna; and for restoring riparian and aquatic communities lost when river systems were modified. The need for research is immediate and continuing as more agricultural land is converted to forestland under various land conservation programs, and as a carbon sequestration market develops. Thus, **land managers need better tools to restore and manage bottomland hardwood forests and associated riparian and aquatic ecosystems that account for the complex ecological processes and wetland functions of these systems. (Problem 4)**

## 10. Approaches to Problem Solution

**Problem 1. Managers need better information on reproductive, seed, and regeneration biology to successfully regenerate and restore bottomland hardwood forests.**

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. 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. The storage of recalcitrant tree seed is currently an insurmountable problem. Scientists working on this problem are now focusing on the carbohydrates, proteins, and over-all physiology of recalcitrant seeds and on innovative biopsy and MRI and CT imaging techniques to examine both seed anatomy and physiology, directed at the problem of storing recalcitrant seed without loss of viability. New studies will examine the biology and biochemistry of flowering, fruiting, and development of seeds of both overstory and understory species.

Element 1. Methods are lacking 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.

Topic 1. 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. Photosynthate allocation in cherrybark oak seedlings under three light levels

Study 2. Growth patterns of pondberry seedlings

Study 3. Effects of flooding on the photosynthetic light response of pondberry

Study 4. Ecophysiology of pondberry relative to light availability and soil flooding

Study 5. Protein expression in flooded roots of cherrybark and Nuttall oak

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

Study 2. Physiology, morphology, and growth of Nuttall oak artificial regeneration beneath an Eastern cottonwood nurse crop

Study 3. Underplanting beneath a partial overstory to establish cherrybark oak regeneration in a minor bottom of southwestern Arkansas

Study 4. A comparison of direct seeding, planting bareroot seedlings, and planting containerized seedlings for establishing cherrybark oak in the Brown Loam Bluffs Region of Mississippi

Study 4. Influence of cutting length on early survival, growth, and above ground biomass production of black willow planted on former agricultural land

Study 5. Seedling quality and field performance of bottomland hardwoods

Study 6. Development and biomass distribution of green ash beneath three levels of overstory

Element 2. The reproductive biology and germination requirements of seeds of many understory species are poorly understood. The relationships between flower and seed production and quality in some key bottomland hardwood species have not been explored.

Topic 1. Studies have been initiated to examine the flowering, pollination, seed production, and germination ecology of key overstory, midstory, and understory species in bottomland hardwood stands.

Study 1. Seed biology and biochemistry of pondberry

Study 2. A study of the germination requirements of overstory, midstory, and understory hardwood species

Element 3. The seed storage physiology of key hardwood species is poorly understood. Storing recalcitrant or desiccation-sensitive seeds of some tree species, most notably some of the oaks, is problematic.

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. Experiments using gas chromatography, accelerated aging, differential scanning calorimetry, and Fourier transform infrared spectroscopy 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. A comparative study of the fatty acids of artificially aged and naturally dehydrated *Quercus nigra* and *Fraxinus pennsylvanica* seeds

Study 2. Ultrastructural changes in desiccating seed

Study 3. Chromosome damage in stored seed

Study 4. Deterioration/fate of acorns under natural conditions.

Study 5. Converting seed herbarium to electronic, accessible medium.

Study 6. The effect of deterioration and desiccation on acorn proteins.

Study 7. Baseline values of nitric oxide in freshly collected, stored, and germinating seeds as a potential indicator of seed vigor.

**Problem 2. Forest managers need improved silvicultural systems and better information on growth and yield, stand development, and the management of insect and disease problems to provide a sustainable yield of desired multiple-use benefits from bottomland forests.**

The team of scientists working on this problem will continue to provide the leadership to develop competent silvicultural and pest management guidelines to enable the sustainable use of southern bottomland hardwood and wetland forests. Long-term studies of silvicultural systems and tree growth in oak-sweetgum stands will continue and will be expanded to additional stands. The concept of stand quality management in southern hardwood forests will be examined through the establishment of a series of new thinning studies. Studies will continue to examine the effects of thinning on residual tree diameter, bole quality, and health. A stand growth model will be calibrated for southern bottomland hardwoods based on crown expansion and density, and that accounts for tree mortality.

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. Studies will continue to examine ways to better understand insect-pathogen interactions in bottomland hardwood forests and in hardwood plantations. Other efforts will include studying the biology of exotic pests in bottomland hardwoods, and other forest tree species, and developing control methods. Practical techniques will be developed to detect pathogen and insect pests, and to minimize pest-caused defects in standing trees and wood in service.

Element 1. Forest managers need effective silvicultural guidelines and the quantitative tools to predict stand development to manage existing bottomland hardwood and wetlands forests for sustainable yields of forest products.

Topic 1. Forest managers need information and quantitative tools to predict the

development of stands over time, and in response to silvicultural practices, for use in making scientifically sound economic decisions.

Study 1. Development of Sylvan stand structure model for southern bottomland hardwoods

Study 2. Supplemental measurements to aid development of Sylvan stand structure model for southern bottomland hardwoods

Study 3. Applying the Landscape Management System (LMS) on southern hardwood forests in the Yazoo National Wildlife Refuge, the Delta National Forest, and Dewey-Wills Wildlife Management Area

Study 4. Development of a guide for managers of bottomland hardwood stands that brings together the current and best available scientific knowledge on the various disciplines within bottomland hardwood forest management

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 stands

Study 5. Release of suppressed cherrybark oak and green ash

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

Study 7. Understanding bottomland hardwood responses to an operational thinning

Study 8. Regeneration, species composition, and stand development after clearcutting in a bottomland hardwood stand

Study 9. Stand quality management of southern hardwood forests – a new series of thinning studies at eight to ten sites across the South

Study 10. Bluff hardwood cutting level study for uneven-aged management

Study 11. Pre-commercial treatments to shorten rotation length in small-poletimber red oak-sweetgum stands

Study 12. Diameter and bole quality responses of residual hardwood poletimber to thinning in sawtimber stands

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

Study 3. Phenological surveys of Woodborers (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. Investigate the biology of woodwasps and their wood-decaying fungal symbionts.

Study 2. Investigate biology of wetwood and associated damage in both hardwood logs and lumber.

Study 3. Investigate wood-boring insects for microorganisms that decay hardwoods.

Study 4. Study the biology of, and interactions between, fungal and bacterial pathogens and insect vectors of disease in sycamore

Topic 3. Managers of bottomland hardwood forests need economical and practical techniques to detect and control insects and diseases causing defects 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

Study 3. Use of molecular methods to identify wood decay fungi

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

Study 1. Investigate biology of exotic wood wasps and symbionts

Study 2. Biological control of exotic forest insects

**Problem 3. Land managers need a more comprehensive understanding of the biology and ecology of warmwater fishes, freshwater mussels, crayfishes, and Neotropical migratory and other birds.**

The RWU will continue to lead and conduct ecological research on warmwater fishes, freshwater mussels, and crayfishes in forested watersheds and birds in bottomland hardwood forests. The RWU also will continue to participate in the development and implementation of monitoring and inventory activities of the Center for Aquatic Technology Transfer. Research will advance conservation of these animals by increasing our understanding of their response to biotic and abiotic factors in stream, 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 or effects occur for life stages spent outside of managed areas. 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, crayfishes, and Neotropical migratory and other birds.

Future research in this problem area will address five areas of common information needs for management of aquatic and terrestrial animals in stream, riparian, and bottomland hardwood ecosystems: (1) development of sampling and monitoring techniques; (2) effects of land-use and environment on community ecology and diversity; (3) population biology; (4) life-history, distribution, and autecology; and (5) linkages between aquatic and terrestrial ecosystems.

Element 1. Development of biological sampling and monitoring techniques for aquatic and terrestrial fauna. A key component of the management of any organism is to monitor trends in its abundance and distribution. Managers need validated methods for sampling and monitoring organisms at a variety of spatial and temporal scales.

Topic 1. Managers lack standardized tools for conducting stream fish, crayfish, and Neotropical migratory bird inventories and assessing integrity of aquatic and bird communities in southern stream and bottomland hardwood systems in relation to management activities.

Study 1. Development of an Index of Biotic Integrity for fish communities of forested watersheds in the middle Gulf Coastal Plain

Study 2. Standardized, quantitative inventory of fishes and fish habitat in Mississippi National Forests

Study 3. Review and critique of the Basin Visual Estimation Technique for monitoring stream fishes

Study 4. Efficiencies of quantitative sampling techniques for crayfish in sand bottom streams

Study 5. Seasonal and annual variability in crayfish numbers in forested streams of the upper Gulf Coastal Plain

Study 6. Development of Southern Region (R8Bird) data storage and retrieval protocols

Study 7. Revision of the "Land Manager's Guide to the Birds of the South"

Topic 2. Managers lack data on the distribution of freshwater mussels on a regional scale in many parts of the South, and lack standardized methods for conducting quantitative surveys of mussel populations, for using survey data to make inferences about resource health, and for detecting temporal trends in diversity and abundance.

Study 1. Species richness and total population size of freshwater mussels in Horse Lick Creek, Kentucky (Daniel Boone National Forest)

Study 2. Changes in Freshwater Mussel Populations in Bankhead National Forest, Alabama

Study 3. Population size of freshwater mussels and potential effects of habitat fragmentation in Shoal Creek, Talladega National Forest, Alabama

Study 4. Inventory of freshwater mussels of Mississippi National Forests

Element 2. Community ecology and diversity in relation to land-use and environmental factors. Managers need information on the effects of landscape-scale processes, local processes, and historical events, including biotic and abiotic factors, on the distribution, abundance, and ecology of aquatic and terrestrial organisms.

Topic 1. A critical information need for management is an understanding of the relationship between habitat characteristics and community composition and how this relationship varies over space and time.

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

Study 2. Distribution, abundance, and diversity of upland stream fishes under variable environmental conditions

Study 3. Patterns of freshwater mussel distribution and abundance in an impounded Gulf Coastal Plain stream

Study 4. Spatial variation in freshwater mussel community structure and habitat use in the Sipsey River, Alabama

Study 5. Prehistoric decline in freshwater mussels coincident with the advent of maize agriculture

Study 6. Distribution and habitat associations of crayfishes in forested watersheds of Mississippi (Mississippi National Forests)

Study 7. Use of spatial distribution of Cerulean Warbler to predict the distribution of other canopy warblers at the local scale

Study 8. Spatio-temporal patterns of diversity and extirpation of freshwater mussels in the Cumberland and Tennessee River basins

Study 9. Geospatial structure, imperilment, beta-diversity, and effects of transplanted fishes on native fishes of the southern United States

Study 10. Distribution, diversity, and seasonality of stoneflies *(Plecoptera)* over a large forested watershed in the Ouachita Mountains

Study 11. Source-sink dynamics in fish assemblages and diversity in seasonally intermittent streams in the Ouachita Mountains

Study 12. Fish community use of small in-stream wood in sand bottom upper Coastal Plain streams

Topic 2. Understanding the effects of large-scale natural phenomena, historical events, and specific land management practices on biological communities is necessary to evaluate long-term outcomes of management

Study 1. Re-establishment of fish and crayfish communities after drought (Mississippi National Forests)

Study 2. Effects of drought on headwater mussel communities

Study 3. Influence of density and dissolved oxygen on condition of the stream-dwelling mayfly, *Stenonema tripunctatum*, from seasonally intermittent streams

Study 4. Response of Cerulean Warbler to forest harvest treatments, Chickasaw

National Wildlife Refuge

Study 5. Response of Cerulean Warbler to forest harvest treatments (silviculture study sponsored by the Cerulean Warbler Technical Group)

Study 6. Evaluation of stand histories and growth conditions of Cerulean Warbler nest and roost trees using Forest Inventory and Analysis data

Study 7. Quantitative assessment of bird community composition and dynamics for forested wetland reference sites in the southern United States

Study 8. Intermediate scale distribution of Cerulean Warblers

Study 9. Prediction of distribution of Cerulean Warblers among bottomland tracts using percolation theory

Study 10. Land-use history in relation to decline and projected recovery of the Rusty Blackbird

Topic 3. 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. Three-dimensional distribution of foliage in Cerulean Warbler breeding habitats in the Mississippi Alluvial Valley and non-breeding habitats in South America

Study 3. Climate change and shifts in Cerulean Warbler breeding range

Study 4. Ecology of Cerulean Warbler during the non-breeding period in South America

Element 3. Population biology issues for management and conservation. An understanding of population dynamics, including recruitment, mortality, migration/immigration, and population growth rates, is essential to predicting and evaluating the long-term influence of land management activities and nonnative species invasions on aquatic and terrestrial species.

Study 1. Population dynamics and demography of freshwater mussels: Application of population models and population viability analysis

Study 2. Population dynamics of Alabama shad in the Pascagoula River system, Mississippi

Study 3. Intrapopulation variation in the demographics of three darter species and

validation of otolith aging techniques (Bankhead National Forest)

Study 5. Population structure of the longear sunfish, *Lepomis megalotis*, in seasonally fragmented streams as inferred from a nested cladistic analysis

Study 5. Cerulean Warbler populations in bottomland hardwood forests, distribution, abundance, and productivity

Study 6. 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

Element 4. Life histories, distributions, and autecology of poorly known organisms with emphasis on sensitive species. The absence of life history and distributional information for many species in the southeastern U.S. has made development of informed management programs difficult at best. Managers need this basic biological information in order to evaluate possible responses of these species to land-use activities and nonnative species invasions.

Topic 1. Many species are composed of a number of genetically distinct entities requiring different management approaches. Patterns of genetic variation are unknown for most nongame aquatic species in the southeastern U.S., making establishment of management units and other management decisions difficult.

Study 1. Range-wide patterns of genetic variation and habitat use in the Yazoo darter

Study 2. Genetic population structure of Alabama shad, an anadromous species, throughout its range

Study 3. Patterns of host-fish use and genetic variation in the freshwater mussel genus *Villosa* in the southeastern United States

Study 4. Interdrainage genetic variation in the crayfish *Orconectes chickasawae*

Topic 2. Reproduction is one of the most highly sensitive events in an organism's life history and reproductive traits are often useful indicators of how a species will respond to environmental changes. Knowledge of an organism's reproductive ecology is critical to its successful management and conservation.

Study 1. Patterns of fecundity and life history traits in freshwater mussels

Study 2. Reproductive biology of the Yazoo shiner, a species endemic to upper Coastal Plain streams in north Mississippi

Topic 3. Information about distribution of crayfishes in Coastal Plain streams is extremely limited, but is essential for determining the impacts of forest management or

invasive species on native crayfishes.

Study 1. Identification of crayfishes inhabiting small streams of the Holly Springs National Forest, Mississippi

Study 2. Distribution and life history of the crayfish *Orconectes chickasawae* in north Mississippi

Study 3. Distribution and life history of the crayfish *Procambarus vioscai* in north Mississippi

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

Study 1. Assist in development of the Cerulean Warbler Conservation Plan (Steering Committee of the Cerulean Warbler Technical Group)

Study 2. Understanding declines in the Rusty Blackbird (*Euphagus carolinus*): an indicator of wooded wetland health (research strategy and proposal from the international Rusty Blackbird Technical Group)

Study 3. Assist in development of the Recovery Plan for Ivory-billed Woodpecker (Ivory-billed Woodpecker Recovery Team)

Element 5. Aquatic-terrestrial linkages. Aquatic-terrestrial linkages occur at the interface between land management and aquatic ecosystems and can assume many forms. Preliminary evidence suggests that aquatic-terrestrial trophic linkages are extensive, especially in forested wetlands and bottomland streams, and will have important implications for the management of bottomland hardwood and riparian forests.

Topic 1. Distributions of some plants are limited by seed dispersal. Information on the roles of animals as dispersers of various seeds will provide managers with valuable information about mechanisms underlying the distributions of both rare and weedy plants.

Study 1. Animal dispersal of the endangered Pondberry (*Lindera melissifolia*)

Study 2. Seed dispersal of the weedy, native wetland plant *Forestiera acuminata* by channel catfish and cedar waxwings and the influence of hydrologic alteration on these avenues of depersal

Topic 2. Nonnative terrestrial plants have the potential to alter nutrient cycles in aquatic systems by changing the quality of leaf litter and the timing of when it is present. Crayfishes are major contributors to the breakdown of leaf litter in southern streams.

Thus, information about crayfish use of native versus nonnative plant material will provide preliminary information about how invasive terrestrial plants alter aquatic nutrient cycles.

Study 1. Consumption and shredding of nonnative kudzu leaves versus native plant leaves by crayfishes native to Coastal Plain streams

**Problem 4. Land managers need better tools to restore and manage bottomland hardwood forests and associated riparian and aquatic ecosystems that account for the complex ecological processes and wetland functions of these systems. (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 restore the functions and values of degraded bottomland hardwood, riparian, and associated aquatic ecosystems. This effort requires the establishment of baseline values for important processes and functions within relatively undisturbed bottomland hardwood ecosystems. Long-term research efforts at the Iatt Creek Ecosystem Research and Management Site and the Sharkey Restoration Research and Demonstration Site will continue. These efforts will be expanded to include new areas of research, and to additional community types.

Another emphasis is on methods to restore animal and plant communities and assess how well restored systems compare with target natural systems. An integrated research approach will continue to examine the ecology, physiological response to light availability and flooding, population genetics, pathology, seed physiology, and seed dispersal of the Federally listed endangered shrub pondberry (*Lindera melissifolia*). The long-term goal of this problem area is to develop environmentally sound forest management practices that simultaneously produce commodities and maintain or improve ecological values, and rehabilitate or restore degraded systems.

There is a void in our understanding of hydrological processes in bottomland hardwood forests and how they affect, and are affected by, agricultural practices. Managers, private forest landowners, and investors need a better understanding of the regional water balance and how hydrologic processes will affect afforestation efforts in the Lower Mississippi River Alluvial Valley. Recently, the Southern Research Station received an increase in funding to address this important research need. A research hydrologist will be hired to lead this research program area in the first year of this RWUD; that scientist will prepare a problem analysis to describe the problem and the approach to be taken over the next five years. This new effort is likely to develop landscape-level models aimed at refining concepts such as Total Maximum Daily Load (TMDL) and Best Management Practices for use in the ecologically sound and economically viable management of forestlands and other natural resources.

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 are poorly understood within the bottomland and adjacent upland or aquatic

systems. Above- and belowground net primary productivity and nutrient transfers are of critical importance to nutrition and growth yet these have been inadequately 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 is 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; this information can then be used in 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 are lacking to maintain diversity, especially that of threatened, endangered, or vulnerable plants in fragmented forest landscapes typical of bottomland hardwoods.

Study 1. Floristic diversity of managed and plantation forests

Study 2. Ecosystem dynamics, physiology, population genetics, seed physiology, seed dispersal, and pathology of the endangered pondberry (*Lindera melissifolia*)

*Note: Study 2 is a series of several studies with one or more studies in each of the scientific disciplines listed.*

Element 2. As management of bottomland hardwood forest ecosystems intensifies, managers will need information on the likely effects of their management practices on these systems and

how this will affect their ability to manage forests, and associated aquatic ecosystems in a sustainable manner. Managers will also require techniques to manage forests, and associated aquatic ecosystems, in ways that will sustain these systems.

Topic 1. As management of existing stands intensifies, in order to meet an increasing demand for fiber from a decreasing available land base, land managers will need to understand the potential effects of intensive management on bottomland hardwood and wetland forests.

Study 1. Assessing cottonwood growth under various fertigation treatments

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 need 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 that may include the use of nurse crops.

Topic 1. Managers need techniques for restoring forest stands, including vertical structure and species diversity, to augment natural soil processes and maintain 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 forest restoration on abandoned agricultural lands on the Sharkey Site, Sharkey County, MS

Study 7. Winter raptor populations and how their predation on small mammal populations is affected by restoration of forests on former agricultural lands on the Sharkey Restoration Research and Demonstration Site, Sharkey County, MS

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

Topic 2. Monitoring treatment results is a prerequisite for sustainable management. Managers and investors need cost-effective monitoring and evaluation procedures for assessing restoration success and biomass accretion.

Study 1. Monitoring techniques for measuring total carbon sequestration

Study 2. Assessing soil quality restoration

Study 3. Survey techniques for monitoring restoration success

Study 4. Bioindicators of functional restoration

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

Element 4. Managers, private forest landowners, and investors need a better understanding of the regional water balance and how hydrologic processes will affect afforestation efforts in the Lower Mississippi River Alluvial Valley.

A research hydrologist will be hired to lead this research program area in the first year of this RWUD; that scientist will prepare a problem analysis to describe the problem and the approach to be taken over the next five years.

| Table 1 | List of Studies that involve CBHR scientists from more than one Team and Location | Team and Location | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Problem Element Topic | Study Title | 1-Regeneration & Reproductive Biology | | 2-Stand Mgmt. & Forest Health | 3-Terrestrial and Aquatic Fauna | | 4-Ecological Processes and Restoration | |
| | | Starkville | Stoneville | Stoneville | Oxford | Stoneville | Pineville | Stoneville |
| 1.1.2 | Ecophysiology of pondberry relative to light availability and soil flooding | | XX | XX | | | | |
| 1.2.1 | Seed biology and biochemistry of pondberry | XX | XX | | | | | |
| 3.2.2 | Quantitative assessment of bird community composition and dynamics for forested wetland reference sites in the southern United States | | | | | XX | XX | |
| 3.3.0 | 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 | | XX | | | XX | | |
| 3.5.1 | Animal dispersal of the endangered Pondberry (*Lindera melissifolia)* | XX | XX | | | XX | | XX |
| 3.5.1 | Seed dispersal of the weedy, native wetland plant *Forestiera acuminata* by channel catfish and cedar waxwings and the influence of hydrologic alteration | XX | XX | | XX | XX | | |
| 4.1.2 | Dynamics of coarse and fine woody debris | | | | | | XX | XX |
| 4.1.3 | Floristic diversity of managed and plantation forests | | XX | XX | | XX | XX | XX |
| 4.1.3 | Ecosystem dynamics, physiology, population genetics, seed physiology, seed dispersal, and pathology of the endangered pondberry (*Lindera melissifolia*) | XX | XX | XX | | XX | | XX |
| 4.1.4 | Hydrologic linkages of bottomland communities with upland and aquatic systems | | | | XX | | | XX |
| 4.2.2 | Effects of short rotation woody crops | | XX | XX | | XX | | XX |
| 4.2.2 | Assessing effects of management on net primary productivity and carbon sequestration | | | XX | | | | XX |
| 4.3.1 | Large-scale comparison of restoration techniques for bottomland hardwoods on former agricultural land | | XX | XX | | XX | | XX |
| 4.3.1 | Restoration of herbaceous, understory, and midstory species on former agricultural land | | XX | XX | | XX | | XX |
| 4.3.1 | Techniques to increase survival of planted and direct-seeded bottomland hardwood overstory species | | XX | XX | | | | XX |
| 4.3.1 | Techniques for rapidly restoring vertical structure using nurse crops | | XX | XX | | | | XX |
| 4.3.3 | Bioindicators of functional restoration | | XX | XX | XX | XX | | XX |
| 4.3.3 | Survey techniques for monitoring restoration success | | XX | | | | | XX |

**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 to incorporate research results obtained over the last 45 years. Our plan for technology transfer for the next five years includes expanding and updating Ag Handbook 181 including chapters on: natural and artificial regeneration; growth and yield of natural and plantation stands; stand management; ecology of bottomland hardwood and wetland forests; protection of aquatic resources and water quality; and forest health. We are planning to incorporate Ag Handbook 181 into the Southern Research Station's Hypertext Encyclopedia.

We will continue to publish research findings in appropriate professional journals and in other more user-friendly formats and 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. This meeting, in which scientists present results of on-going work, is open to everyone and attendance typically runs between 75 and 125 people. 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; short courses through Mississippi State University on bottomland hardwood regeneration and on stand management; and participation in short courses and training workshops sponsored by other organizations. Informal training is provided to stakeholders on a regular basis.

Dissemination of research results to multiple audiences requires multiple outlets. The most recent findings of our research will be presented in short courses and seminars; research papers; color-illustrated guides; and CD ROMs. We anticipate greater utilization of Internet technology for disseminating our research. This already occurs to some extent, for example through the SRS WebPages, current publications can be downloaded and printed in "pdf" format. We plan to make selected older publications available as we scan and edit them. Several studies now underway could lead to the development of commercial products, possibly through CRADAs.

**Environmental Considerations:** Proposed research activities in this Research Work Unit Description are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values. The environmental effects of specific actions will be considered during the development of study plans, as well as the existence of extraordinary circumstances related to any proposed action, and categorical exclusion will be documented as a part of the study plan according to FSH 1909.15, Chapter 30. Where environmental concerns exist regarding particular studies, these may be evaluated within individual study plans, or by Environmental Assessments prepared by federal agency cooperators. For example, our work at Iatt Creek on the Kisatchie National Forest is covered by several EAs. Where studies are conducted in natural areas or other preserves, all agency regulations and guidelines are followed. All relevant federal regulations are followed in collecting animals and working with endangered plants, including consulting with the U.S. Fish and Wildlife Service as per Section 7 of the Endangered Species Act of 1973, as amended. Several members of our staff have been granted certified pesticide applicator status and maintain their certification. Relevant OSHA 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 Research 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. The Unit has contracted with a mathematical statistician to review and give advice on all study plans and manuscripts. 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.

## 11. Staffing and Budget

The scientific staff of the Research Work Unit consists of thirteen permanent, full-time scientists, (including the project leader) plus three post-doctoral scientists (Table 1). There are currently 13 permanent and 6 temporary, full-time technicians, a chemist, an IT specialist, three full-time and one part-time administrative staff, and seven SCSEP positions within the RWU. Summer student and international volunteer staff averages 8 to 10 annually.

Table 1. Current staffing, including post-docs.

| Problem Number/Title | SY | Scientists |
|---|---|---|
| 1-Regeneration & Reproductive Biology | 2<br>(1) | Gardiner (Team Leader), Vozzo, *Research forester (afforestation and stand development)*[1] |
| 2-Stand Development & Forest Health | 4<br>(1) | Leininger (Team Leader), Meadows, Schiff, Wilson, *vacant Biometrician* |
| 3-Terrestrial and Aquatic Fauna | 4 | Warren (Team Leader), Adams, Haag, Hamel |
| 4-Ecological Processes and Restoration | 3<br>(2)<br>3 | Devall (Team Leader), De Steven, Meier, *one or two Research Hydrologists*<br>Post-docs: Echt, Hawkins, Lockhart |

1. Italicized titles, and numbers in parentheses, indicate additional staff needed within the period covered by this RWUD.

The work described in this Research Work Unit Description will require $5.5 million per year. The current annual Congressional appropriation (FY 2006) for this unit is $4.78 million. Additional research funds have been received from the US Army Corps of Engineers, US Forest Service State and Private Forestry, various other federal and State agencies, and non-governmental organizations as a result of successful competition by RWU scientists for grants. If full funding is not available to complete the research described in this RWUD, work on reproductive biology and ecology of bottomland hardwood forests will be reduced or eliminated.