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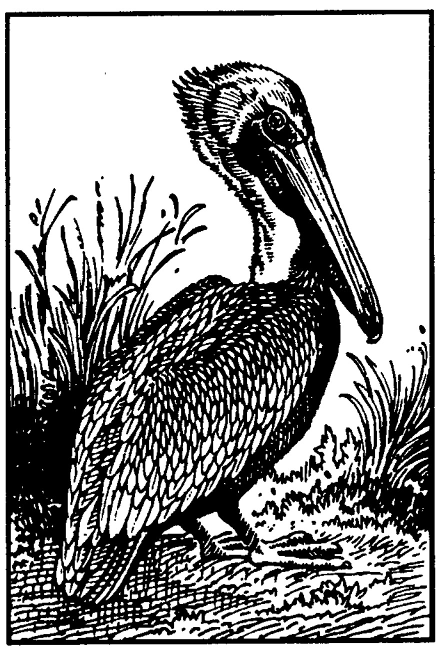
Wetlands Research Program Technical Report WRP-RE-18

Reforestation of Frequently Flooded Agricultural Fields: A Compendium of Results from Research Conducted at the Lake George Wetland and Wildlife Restoration Project, Mississippi

by Hans M. Williams, Monica H. Craft, Gary L. Young


August 1997 – Final Report

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	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

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Final report

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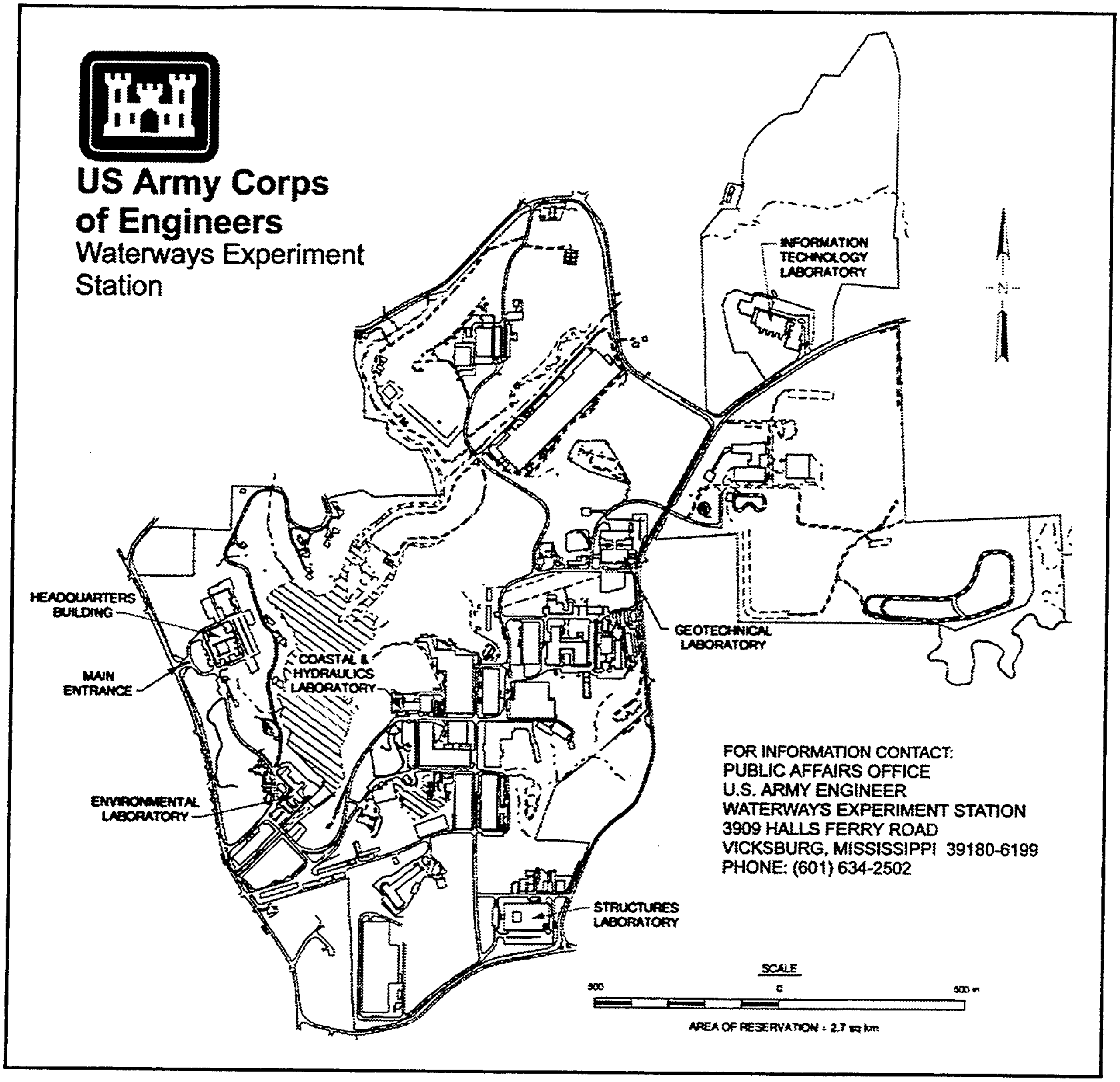

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Wetland Restoration

Reforestation of Frequently Flooded Agricultural Fields: A Compendium of Results from Research Conducted at the Lake George Wetland and Wildlife Restoration Project, Mississippi (TR WRP-RE-18)

ISSUE:

In the Mississippi Delta, initiatives by Federal, State and private agencies will attempt to restore unproductive, frequently flooded agricultural fields back to bottomland hardwood wetlands. However, early reforestation efforts by direct seeding or planting bare-root seedlings have been only marginally successful. Prolonged flooding and poor seedling quality are two reasons for the low seedling survival. Bottomland hardwood restoration planners need guidance on applied issues such as species selection, stock type selection, planting schedules, and site monitoring.

RESEARCH:

The objective of the Lake George Wetland and Wildlife Restoration Project is to restore functioning bottomland hardwood wetland habitat by reforesting 3,600 ha of agricultural fields located in the Mississippi Delta. The Lake George Project provided an opportunity to conduct applied research on several bottomland hardwood reforestation topics. University and Federal agency scientists conducted studies on matching tree species to the site, selecting plant stock type, selecting when to plant, and monitoring early habitat development following planting.

SUMMARY:

Lake George research indicated that planting bare-root seedlings on sites that flood infrequently can be a successful means of establishing a bottomland hardwood forest. Direct seeding may also be successful on the drier sites, but less so than planting seedlings. Planting container seedlings may provide an answer to the poor survival observed for bare-root seedlings or direct seeding on flood-prone sites. Following planting, the Lake George sites quickly provide valuable pioneer successional stage habitat for vegetation and animal species.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U. S. Army Engineer Waterways Experiment Station (WES) Library, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS report numbers may also be requested from the WES librarians.

About the Authors:

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Contents

Preface

The work described in this report was authorized by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Restoration and Establishment of Wetlands, Task Area V, of the Wetlands Research Program (WRP). Dr. Mary C. Landin, Wetlands Branch, Ecological Research Division (ERD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), was the Task Area Manager. The work was performed under Research Area 4, "Bottomland Hardwood Restoration," for which Dr. Steve Sprecher, Wetlands Branch, was Principal Investigator. The Research Area was a part of Work Unit 39761, for which Dr. Landin was Principal Investigator. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for this work. Mr. David Mathis (CERD-C) was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-AA) served as the WRP Technical Monitors' Representative. Dr. Russell F. Theriot, WES, was Program Manager of the WRP.

This report was prepared by Dr. Hans M. Williams under Contract No. DACW39-95-M-3814. Dr. Williams is an Assistant Professor, College of Forestry, Stephen F. Austin State University, Nacogdoches, TX. Ms. Monica H. Craft, Wetlands Branch, and Mr. Gary Young, U.S. Army Engineer District, Vicksburg, are co-authors. Dr. Sprecher and Dr. Landin served as technical reviewers of the manuscript.

The work was performed under the direct supervision of Dr. Morris Mauney, Chief, Wetlands Branch; Dr. Conrad J. Kirby, Chief, ERD; Dr. John W. Keeley, Assistant Director, EL; and Dr. John Harrison, Director, EL.

Numerous individuals were involved in the successful research conducted at the Lake George Project. Thanks are extended to Messrs. Steve Reed, Gary Young, and Steve Knight, U.S. Army Engineer District, Vicksburg; Mr. Don Brazil, Mississippi Department of Wildlife, Fisheries, and Parks; Dr. Stephen Schoenholtz and Dr. Masato Miwa, Mississippi State University; Drs. Harvey Kennedy, Jeff Goeltz, and D. W. Carlson, U.S. Forest Service; and Dr. Tom Roberts and Mr. Kenneth Munson, Tennessee Technological University. The authors give special thanks to Ms. Barbara Kleiss, Dr. Charles Klimas, Dr. Sprecher, Dr. Jim Wakeley, Dr. Landin, Mr. Ellis Clairain, Mr. Richard Smithhart, Mr. Kyle Anderson, and Ms. Toshma Thomas for their assistance in these studies.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin.

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1 Introduction

The Lake George Wildlife and Wetland Restoration Project involves the acquisition, reforestation, and management of approximately 3,600 hectares (ha) of frequently flooded agricultural lands in Yazoo County, Mississippi. The land was purchased from a willing seller in 1990 by the U.S. Army Engineer District, Vicksburg. The property is being reforested as mitigation for unavoidable terrestrial wildlife losses from construction and operation of the Yazoo Area and Satartia Area Backwater Levee Projects. The levee system was completed in 1987.

Backwater Levee Project Impacts

Unavoidable adverse impacts from levee construction included project-induced clearing of 486 ha of bottomland hardwoods and the right-of-way clearing of 2,388 ha of bottomland hardwoods. Impacts to the quality of existing hardwoods from the reduction in seasonal flooding were also considered. Impacts to habitat and terrestrial wildlife were estimated using the Habitat Evaluation Procedures (HEP) developed by the U.S. Fish and Wildlife Service. An estimated 526,950 annualized habitat units were lost from impacts to bottomland hardwoods and their associated wildlife resources.

Mitigation

The mitigation planning objective was 100 percent in-kind replacement of the 526,950 annualized habitat units. The justification and guidance for mitigation are provided in Engineer Regulation 1105-2-50: "Fish and wildlife mitigation measures shall be evaluated according to their ability to either avoid, minimize, or compensate for adverse effects on significant fish and wildlife resources when compared to the 'future without plan' conditions. The extent of, and justification for, mitigation of the adverse effects of an alternative plan shall be based upon the significance of the resulting losses, compared to the combined monetary and nonmonetary costs required to carry out the mitigation measures. Justification shall not be based solely on the measure's ability to produce monetary benefits equal to its costs."

This project is being conducted under the authority of the Water Resources Development Act of 1986 (Public Law 99-662).

Selection of Mitigation Alternative

Four mitigation alternatives were considered: (a) development of existing public lands, (b) fee title acquisition and management of existing bottomland hardwood, (c) perpetual land use easements, and (d) fee title acquisition, reforestation, and management of agricultural lands. The development of existing public lands was eliminated because all public lands in the area were being managed to the maximum extent practical. The fee title acquisition of existing bottomland hardwoods was eliminated because of the lack of availability and because this method simply results in the transfer of ownership.

The concept underlying the use of perpetual easements for mitigation is that it prevents further clearing of bottomland hardwoods. This alternative, however, was eliminated because the 1985 Food Security Act ("Swampbuster") discourages further conversion of bottomland hardwoods to agricultural production. The fee title acquisition and reforestation of agricultural lands was selected because it provided the best method for providing tangible compensation, and it represented an ecosystem-based approach to mitigation.

Study Area

The Lake George Project is in the lower Mississippi Delta. The property is relatively flat and poorly drained. Predominant soil types are Sharkey (very fine, montmorillonitic, nonacid, thermic, Vertic Haplaquepts), Forestdale (fine, montmorillonitic, thermic, Typic Ochraqualfs), and Dundee (fine-silty, mixed, thermic, Aeric Ochraqualfs) (U.S. Department of Agriculture (USDA) Natural Resources Conservation Service 1975). About 2,670 ha are protected by a levee system on the eastern side of the property. However, about 405 ha are unprotected and subject to backwater flooding from the Mississippi River. Protected areas are sometimes subject to interior ponding when gravity flow cannot be evacuated. Flooding generally occurs during winter and spring, particularly April and May. The 3,600-ha tract is between the 23,877-ha Delta National Forest to the west and the 8,903-ha Panther Swamp National Wildlife Refuge to the east. Adjoining the southern border of the national forest is an 8,903-ha privately owned bottomland hardwood forest. Together these lands represent about 45,000 ha of contiguous bottomland hardwood wetlands (BLHW). Completion of the Lake George Project will add another functional wetland ecosystem in the lower delta and enhance the cumulative functional capacity at the landscape level.

Management

The Mississippi Department of Wildlife, Fisheries, and Parks under contract and license with the Department of the Army is responsible for the administration, operation, and maintenance of the Lake George Project for a period of 50 years. A comprehensive, long-term management plan is being jointly developed by the U.S. Army Corps of Engineers; Mississippi Department of Wildlife, Fisheries, and Parks; and the U.S. Fish and Wildlife Service.

Reforestation Status

Reforestation began in 1991, and about 486 ha per year have been reforested. About 2,023 ha had been reforested through 1995. Because of extensive flooding after the 1991 season, some areas were replanted in 1992. Those lands not selected for reforestation during the planting season remain under an agricultural release to eliminate the need for site preparation. Plantings include a combination of direct seeding, bare-root seedlings, and container seedlings. Reforestation is scheduled to be completed in 1997.

Research

A cooperative program to document and evaluate bottomland hardwood restoration techniques, wildlife utilization, and mitigation effectiveness was coordinated by the U.S. Army Engineer Waterways Experiment Station (WES). Funding for the program was derived from the U.S. Army Engineer Wetlands Research Program (WRP) and the Vicksburg District. Participating organizations included WES; the Vicksburg District; U.S. Forest Service; U.S. Fish and Wildlife Service; Mississippi Department of Wildlife, Fisheries, and Parks; Mississippi State University; Tennessee Technological University; and Alcorn State University. The objective of this report was to summarize the early results from the studies conducted at Lake George.

2 Lake George Research Results

Matching Species to the Site

Wetland restoration refers to the reestablishment of a wetland where one previously existed. More precisely, wetland restoration is the placement of a similar functional wetland in the same location where a wetland had been degraded or lost (Landin 1993). Restoration assumes at least one of the four necessary parameters for wetlands is present, and is usually much more predictable and less expensive (Landin 1993). The advantage of restoring BLHW on frequently flooded agricultural fields is that minimal effort is required to restore wetland hydrology. If tree planting occurs immediately after harvest of an agricultural crop, site preparation is usually not required. A major objective for any reforestation project is to place the right tree species in the right place at the right time (Smith 1986). Flood-tolerant tree species need to be planted in areas subject to prolonged periods of flooding or soil saturation (Table 1). Guidance for where to plant each tree species can be obtained by noting the location of tree species in a reference forest similar in topography, soils, and hydrology to the project site (Figure 1). The number of appropriate tree species to plant is limited only by what is available from local seedling vendors.

The agricultural fields selected for wetland restoration usually have significant man-made changes in hydrology. These sites are still desirable, but the location, timing, type, frequency, duration, and depth of flooding may have been altered. Lake George typifies potential wetland restoration sites within the Mississippi Delta by having numerous drainage channels and a levee system (Figure 2). Consequently, the natural interrelationship between the soils, the ridge and swale topography, and the hydrology observed in a nearby, relatively undisturbed forest may no longer apply to the Lake George site.

The results from two WRP studies conducted at Lake George indicate that understanding site conditions is an important step prior to making decisions on matching tree species to particular locations. The study by Miwa (1993) investigated the survival and growth of four oak species hand-planted on a common soil catena found at Lake George and throughout the Mississippi Delta. The study was

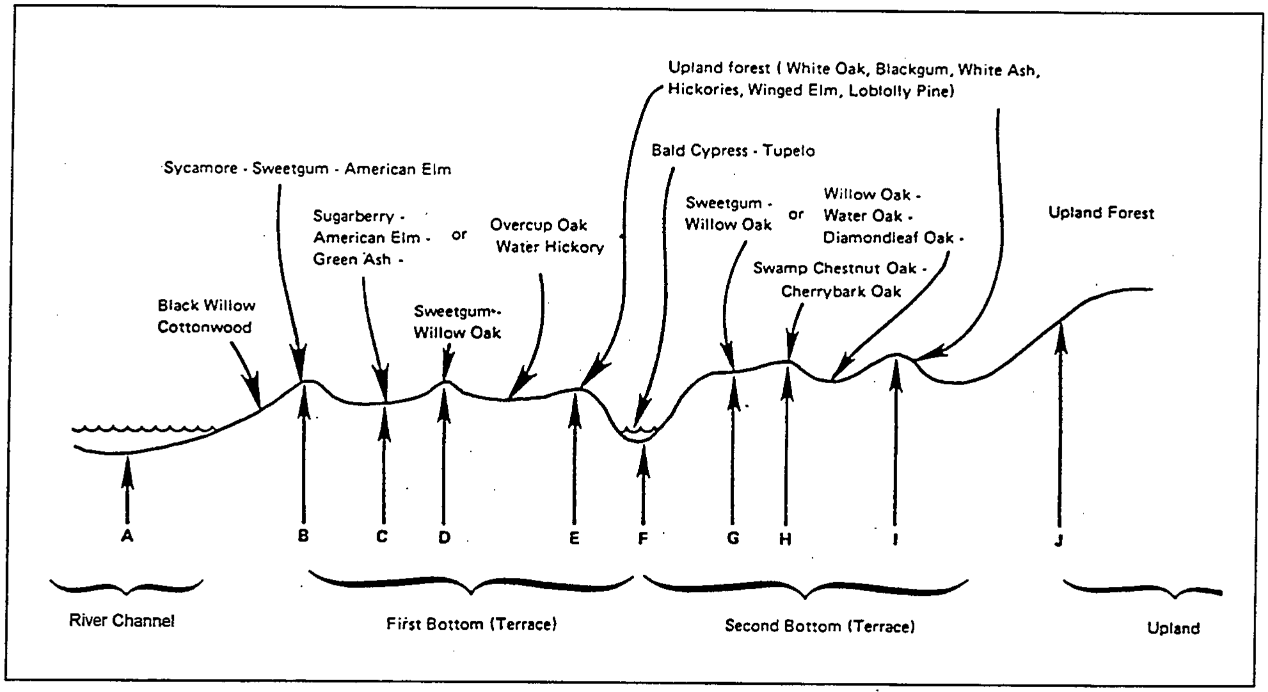

Figure 1. The correspondence between alluvial floodplain microtopography and forest cover types (adapted from Wharton et al. 1982)

located west (or outside) of the West Levee at Lake George (Figure 2). Acorns and 1-year-old bare-root seedlings of Nuttall oak (*Quercus nuttallii*), Shumard oak (*Quercus shumardii*), water oak (*Quercus nigra*) and cherrybark oak (*Quercus falcata* var. *Pagodaefolia*) were each hand-planted in December 1991 on a Dundee soil series (fine-silty, mixed, thermic, Aeric Ochraqualfs), Forestdale soil series (fine, montmorillonitic, thermic, Typic Ochraqualfs), and Sharkey soil series (very fine, montmorillonitic, nonacid, thermic, Vertic Haplaquepts) (USDA Natural Resources Conservation Service 1975). The Dundee soil is usually located on the ridges while the Sharkey soil is found in the swales. The Forestdale soil is located between the Dundee and Sharkey soil. The Forestdale and Sharkey series are classified as hydric soils (USDA Natural Resources Conservation Service 1991). The second study, initiated in January 1992, involved hand-planting cherrybark oak, water oak, and Nuttall oak as bare-root seedlings on a Dundee-Forestdale-Sharkey soil catena located east (or outside) of the East Levee at Lake George (Williams et al. 1992) (Figure 2).

The observations made during the first growing season after planting would suggest that soil conditions were similar for both study sites. No significant surface flooding was observed at either study location during the 1992 growing season. Water tables on the west-side study sites appeared to remain below the root zone (15-20 cm) (Figure 3). Gravimetric soil moisture content determined periodically throughout the growing season was similar between study sites for each soil series (Table 2). Miwa postulated that the lack of soil moisture stress (flooding or drought) may have resulted in the high first-year seedling survival observed for all species on each soil type (Table 3). However, for the east-side study, a correlation

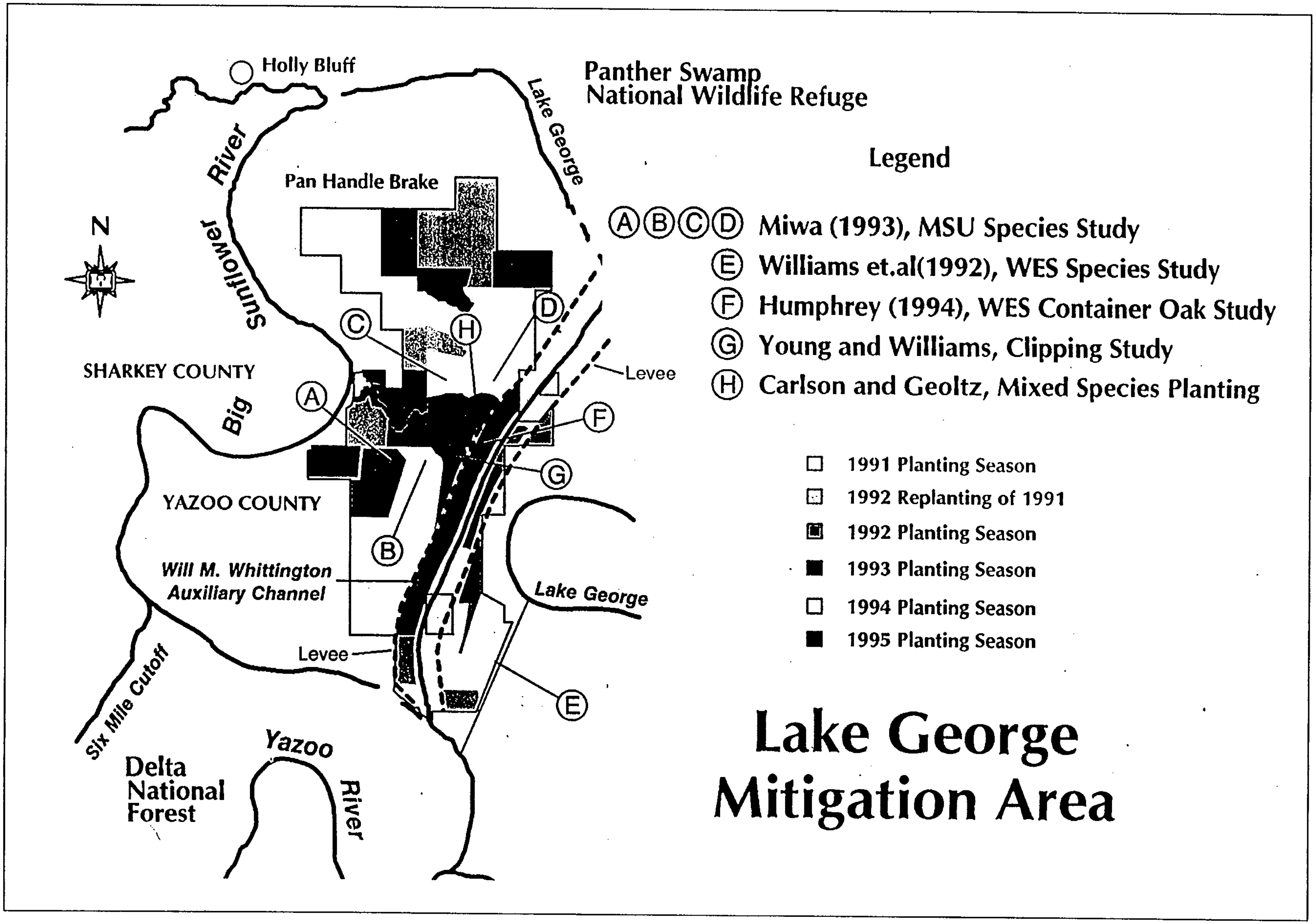

Figure 2. Location map of the Lake George Wildlife/Wetland Restoration Site

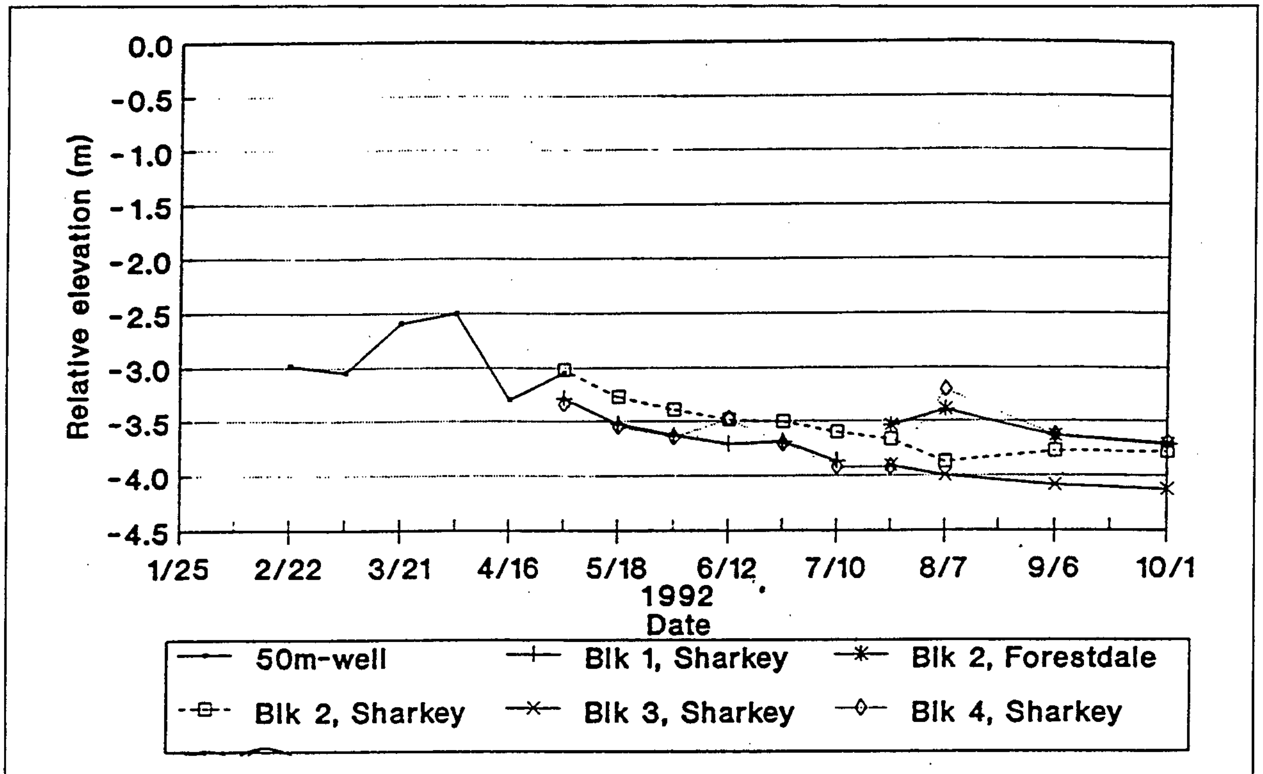

Figure 3. Subsurface groundwater changes on the west side of the levee system at the Lake George project site

between species flood tolerance and soil series was more apparent. Cherrybark oak, a bottomland hardwood species, is considered to be flood intolerant (Clark and Benforado 1981). The first-year survival of the cherrybark oak seedlings was lower on the hydric soils (Table 4).

Direct observations comparing the two study locations suggest that the east side is significantly wetter than the west side (Figure 4). During planting on the east side, shallow rainwater ponding was evident throughout large portions of the Forestdale and Sharkey soil locations. Despite the lack of significant surface flooding, anaerobic conditions created by rainwater ponding could have contributed to the poor first-year survival of the cherrybark oak seedlings. For the east-side study, the beginning of subsequent growing seasons (1993, 1994, and 1995) was marked by prolonged backwater flooding on the Forestdale and Sharkey soils. The west-side study locations remained relatively dry. Direct observations in August 1994 of the east-side study plots indicated that only the moderately flood-tolerant Nuttall oak remained in the Forestdale and Sharkey soil locations.

As suggested by Miwa (1993), all the species studied may be planted across the range of soil conditions found over a large portion of the west side of Lake George. Because of the wildlife and timber value, cherrybark oak is a desirable bottomland hardwood tree species. The knowledge that many of the mapped hydric soils no longer flood or flood at a lower frequency, depth, and duration could allow the restoration planner to increase cherrybark oak plantings on the site.

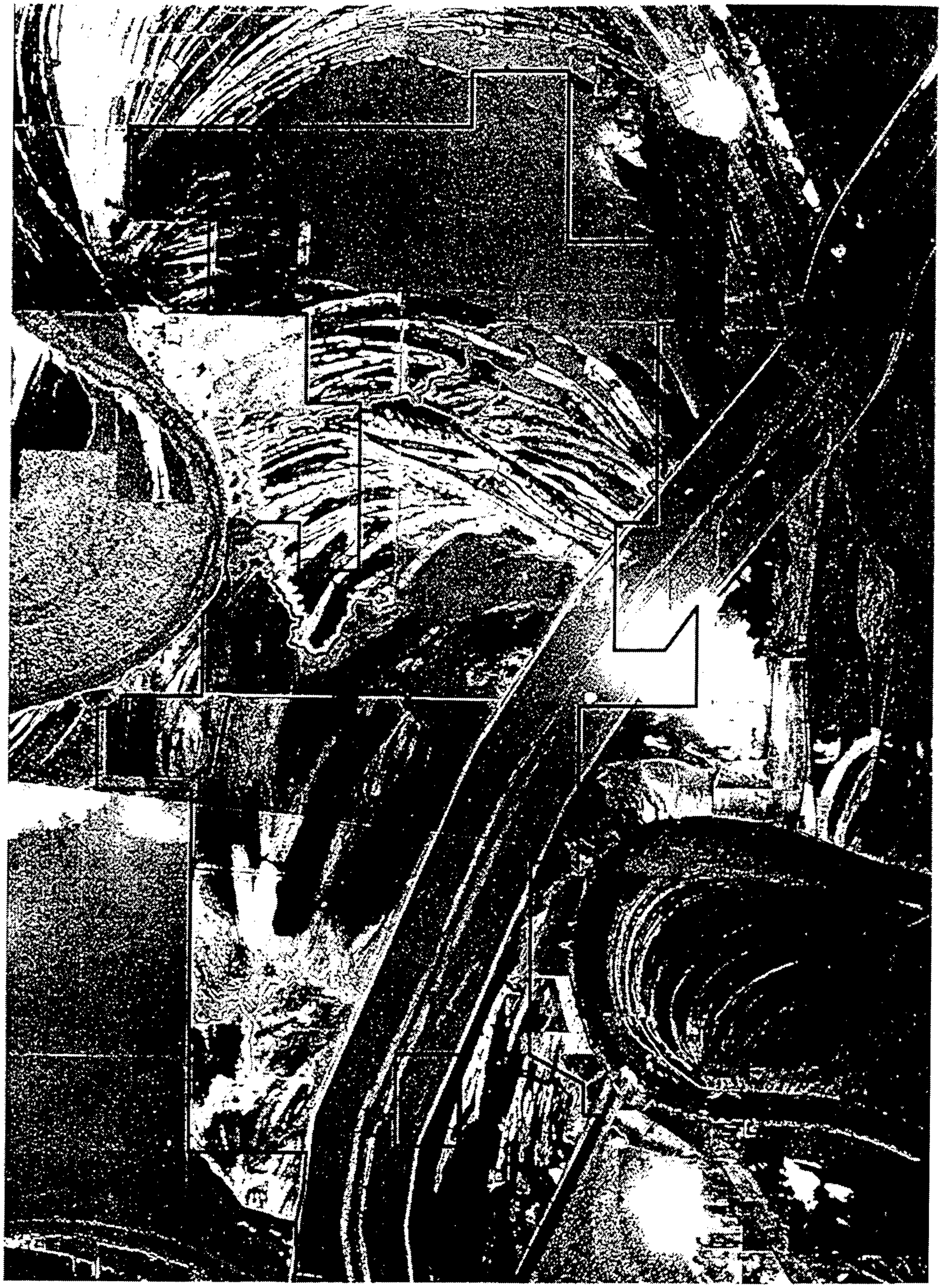

Figure 4. Aerial photo of flooding at Lake George, Mississippi, in 1979

In summary, the successful matching of tree species to locations on a wetland restoration site depends primarily on understanding hydrologic characteristics. Unfortunately, hydrology is the least understood factor defining a wetland. The restoration planner should combine thorough offsite investigative techniques with onsite observations to gain an understanding of the hydrology. Offsite techniques include studying U.S. Geological Survey (USGS) 7.5-minute quadrangle maps, aerial photographs, satellite imagery, and USDA Natural Resources Conservation Service (NRCS) Soil Surveys. The Corps or USGS may have water-level recorders on nearby water bodies. The water stage data may provide direct information regarding the location, frequency, duration, and depth of flooding on the restoration site. Onsite observations begin by visiting the potential restoration site and a reference forest when the hydrologic influences are the greatest. In the Mississippi Delta, potential BLHW restoration sites would usually be visited during the winter and early spring. Onsite evaluation techniques such as those developed by Baker and Broadfoot (1979) may also prove effective in determining where to locate the desired tree species.

Planting Methods: Stock Type and Planting Time

The reforestation of flooded agricultural fields can be accomplished by two means: direct-seeding or planting seedlings (Allen and Kennedy 1989). Natural regeneration is usually not an option because of the lack of a nearby seed source and the desire to control species composition. Direct-seeding involves the placement of seed by hand or machine into the mineral soil. If soil conditions and hydrology are favorable, oak species can be successfully established by the direct-seeding method (Johnson and Krinard 1985). The cost of reforestation by direct-seeding can be one-half less than planting seedlings (Bullard et al. 1992). However, seedling establishment will most likely be poor when floodprone sites are direct-seeded (Kennedy 1990).

Bottomland hardwood reforestation is accomplished using primarily 1-year-old bare-root seedlings (Johnson and Krinard 1985). Stocking levels are usually higher following the planting of bare-root seedlings versus that of direct-seeding (Allen 1990; Wittwer 1991). Bare-root hardwood seedlings survive best when planted on moist but well-drained soils (Kennedy and Johnson 1984). However, bare-root seedling establishment can be severely reduced on sites that experience prolonged flooding. Backwater flooding during the 1991 growing season on Forestdale and Sharkey soils at Lake George completely inundated bare-root seedlings planted the previous winter. The poor seedling survival observed required that the sites be replanted.

The poor survival of bare-root seedlings planted prior to the 1991 flood stimulated the need for studying alternatives for the artificial regeneration of frequently flooded sites (areas that flood in most years). Interest increased regarding the survival and growth potential of seedlings grown in containers. The most notable success story for the use of container seedlings in the southeastern United States is with longleaf pine (*Pinus palustris L.*) (Vanderveer 1993). Studies are lacking that investigate the use of container bottomland hardwood seedlings. Advantages associated with container seedlings include greater flexibility in propagation or planting times and the reduced physical damage and exposure of root systems during planting (White, Schneider, and Lemmien 1970). Container seedlings are usually more expensive than bare-root seedlings. Also, shipping the bulky nursery material (container + seedling) and the handling of the containers during planting are disadvantages (Smith 1986). However, the higher survival observed for container seedlings on adverse sites may justify the additional expense and container handling problems (Forbes and Barnett 1974; Yeiser and Paschke 1987; Barnett and McGilvray 1993). The planting of an undisturbed root system still in contact with the growing medium may account for the high survival and growth observed for container seedlings on adverse sites (Tinus 1974).

A study conducted by Craft (1994) compared the survival and growth of container, bare-root, and direct-seeded Nuttall oak planted on a frequently flooded agricultural field. In addition, the study investigated the effect of planting date on survival and growth in relationship to stock type. The study was located on a flood-prone Sharkey soil west of the Will Whittington Canal but inside the west-side levee. For the direct-seeding treatment, seed was purchased from a local seed vendor. Seed was cold-stored until a stratification treatment was applied 60 days prior to field sowing. Bare-root seedlings were purchased from a local nursery in January 1993 and cold-stored until planting. Propagating the container seedlings involved sowing seed from the same seed lot used for the direct-seeding treatment in 154-cm^3 plastic cone containers filled with a 1:1 ratio of peat and vermiculite. Container seedlings were grown outside in a 50 percent shadehouse located at WES. Seedlings were watered and fertilized as needed until planting. Seed was hand-sown, and the 1-year-old seedlings hand-planted in January, February, March, and June 1993.

Minimum seedling size recommendations for bottomland hardwood bare-root planting stock are 3.8-mm root-collar diameter, 45-cm shoot height, and 20-cm taproot length (Allen and Kennedy 1989). Both the bare-root and container Nuttall oak seedlings exceeded the minimum size recommendations (Table 5). The bare-root seedlings were significantly larger than the container seedlings. However, the root biomass measurements are misleading. The bare-root seedling root systems were heavier, but consisted primarily of a main taproot with a few primary lateral roots. The container seedling roots were lighter but could be characterized as a dense, fibrous system.

Weather conditions for the January, February, and March plantings were cloudy, windy, and cool, and soil conditions were moist (Table 6). The June planting date was sunny, windy, and hot, and the soil conditions were much dryer. Significant cracking of the montmorillonitic Sharkey soil was observed. Following the March 1993 planting, backwater flooding from the Big Sunflower River completely inundated the seedlings for about 8 weeks. The container seedlings appeared to withstand the flooding stress and the apparent June drought stress better than either the bare-root or direct-seeded seedlings. First-year survival for the container seedlings exceeded 80 percent regardless of planting date (Table 7). Bare-root seedling survival was about 60 percent for the January and February plantings, but survival dropped for the March and June plantings. First-year survival of seedlings from direct seeding was lowest and declined as the sowing date occurred later in the year.

Growing seedlings in well-designed containers promotes the development of a fibrous root system (Elliott 1987). Maintaining root to soil contact following planting is crucial to seedling survival. Jeopardizing the root to soil contact is the reduction of existing root systems and declines in the initiation of new roots caused by flooding (Kozlowski, Kramer, and Pallardy 1991). The loss of existing roots from the container seedlings was to be expected during the spring 1993 flood. However, the better survival observed for the container seedlings may be attributed to the fibrous root system providing a greater residual surface area for new root initiation following the flooding stress. The fibrous roots of container seedlings may have greater surface area for oxygen absorption during flooding (anaerobic conditions).

Typically, tree seedling planting occurs from mid-December to early March in the Mississippi Delta. Unfortunately, that is when flooding and soil saturation are usually the greatest. The survival results support the advantage container seedlings have over bare-root seedlings regarding the scheduling of planting. During the 1993 flood, the container seedlings remained outside at the WES greenhouse facilities. Seedlings were watered and fertilized as needed. The bare-root seedlings and acorns remained in cold storage. Container seedlings were in full leaf for the June planting. Increased mortality was expected considering the high evapo-transpiration stress imposed on the seedlings. However, a fibrous root system provides a greater surface area for the absorption of water and enhances the tolerance of planted seedlings to drought (Kramer 1983). Consequently, 1-year-old container seedlings can be kept viable until floodwaters recede, and then planted. The feasibility of fall planting of container seedlings needs to be investigated. Fall planting may allow roots to become well-established prior to the flooding stress.

The significant decline in bare-root seedling survival for the March and June plantings may be attributed to storage stress. Following the January 1993 lifting at the nursery, about 100 to 200 one-year-old Nuttall oak seedlings were placed in large kraft bags prior to cold storage (about 5 °C). Because of the seedling size, the storage bags could not be completely closed. The roots of the bare-root seedlings began to dry out within 3 weeks after placement in cold storage, despite being packed in a synthetic mulch. Attempts were made to keep the roots moist. However, the prolonged cold storage, forced by the flood, led to other problems such as mildew. Long-term storage of bare-root seedlings may be avoided by arranging to pick up from the nursery the number of seedlings that can be planted each day. However, inaccessibility of the planting site due to flooding still may force long-term storage. In order to facilitate seed bed preparation for the next seedling crop, bare-root nurseries typically complete lifting of seedlings by the end of February. If the planting site is flooded, storage of the bare-root seedlings will be necessary.

A partial explanation for the low seedling survival observed for direct seeding was that a significant number of the acorns were found on the soil surface following the flood. The acorns were sown at a 5-cm depth. The shrink and swell of Sharkey soils in response to cycles of drying and wetting may have forced the acorns to the surface. The acorns may have to be sown deeper in order to prevent their displacement to the surface. Sowing acorns at depths to 15 cm can be successful, but the best seedling percentage appears to occur when acorns are sown at a depth of 5 cm (Johnson and Krinard 1985).

The Lake George studies by Williams et al. (1992) and Craft (1994) support the statement by Kennedy (1993) that the early growth in height of planted oak seedlings can be slow. The planted seedlings were actually shorter following the first growing season due to shoot dieback (Tables 4 and 7). The container seedlings experienced less dieback than the bare-root seedlings, especially when planted in January or February.

Miwa (1993) observed a net positive first-year height growth (Table 3). The greater flooding stress on the Williams et al. (1992) and Craft (1994) sites may have promoted the shoot dieback. The early slow growth or shoot dieback of planted seedlings may increase mortality when the seedlings are inundated. Tree species considered flood tolerant when mature may be susceptible to prolonged inundation as seedlings (Kozlowski, Kramer, and Pallardy 1991). Efforts in the nursery to grow tall seedlings less susceptible to complete inundation will be wasted if the seedlings quickly die back to the soil surface during the first year in the field. Further research is needed regarding the nursery propagation of bottomland hardwood seedlings and the phenomenon of shoot dieback. Research is also needed on the biology, logistics, and economics of planting large container stock on floodprone agricultural fields.

In summary, the early results suggest that container seedlings may exhibit greater survival than bare-root seedlings when planted on floodprone agricultural sites. The lack of significant root disturbance during seedling handling may promote the higher survival. Using container seedlings also may provide greater flexibility in the scheduling of planting times. In particular, container seedlings can be successfully planted in late spring following the recession of floodwaters. The container seedlings can be maintained out-of-doors until planted. Bare-root seedlings would most likely have to be held in cold storage until the floodwaters receded. On sites where flooding is infrequent, good seedling survival may be expected when planting bare-root seedlings or direct seeding. The lack of flooding or prolonged soil saturation may have led to the good first-year survival observed by Miwa (1993) for bare-root and direct-seeded seedlings. The ridge and swale topography and the significant hydrologic modifications at Lake George allow flexibility in assigning stock types to certain locations. The ridges (Dundee soil series) that flood infrequently could be direct seeded. Midslope sites (Forestdale soil series) that flood periodically could be planted with bare-root seedlings. Swales (Sharkey soil series) that flood in most years could be planted with container seedlings. Midslopes or swales that no longer flood or flood infrequently could be direct seeded or planted with bare-root seedlings. The reductions in regeneration costs by using direct seeding where appropriate may justify the additional planning required when using three stock types.

Monitoring Early Habitat Development

Monitoring the Lake George project will determine whether the restored BLHW functions are effective in replacing the lost wetland functions (Quammen 1986). The functions to be restored should be determined during project planning. Lake George was designed primarily to restore bottomland hardwood wildlife habitat. Measuring the survival of planted seedlings is important but insufficient in determining whether wildlife habitat is being restored. In order to gain a better understanding of restoration success, monitoring the development of vegetation characteristics should coincide with measurements of wildlife use and soil physical and chemical properties (D'Avanzo 1990). A study funded primarily by the Vicksburg District and WES and supported by the WRP evaluated the early habitat development and wildlife use for planted sites at Lake George (Morgan 1993).

In June 1991, six permanent plots were established on sites planted the previous winter. Each permanent plot was subdivided into subplots based on topographic position. Field sampling that investigated the composition and growth of successional vegetation and the composition and densities of avian and mammal communities occurred during the summer of 1991 and the winter, spring, and summer of 1992.

About 41 plant species were observed during the first summer following planting (Table 8). Total canopy cover was almost 100 percent regardless of topographic position. Johnson grass (*Sorghum halepense*), cocklebur (*Xanthium strumarium*), morning glory (*Ipomoea* sp.) and trumpet creeper (*Campsis radicans*) were the dominants during 1991. Johnson grass dominated on the ridgetops while morning glory and trumpet creeper were more prevalent in the swales (Table 9). Trumpet creeper dominated the ridge tops in 1992 (Table 10).

Numerous bird species were observed during the summer of 1991 (Tables 11 and 12). The most abundant breeding birds appeared to be the red-winged blackbird (*Agelaius phoeniceus*) and the dickcissel (*Spiza americana*). In addition to the red-winged blackbird, the swamp sparrow (*Melospiza georgiana*) and the song sparrow (*Melospiza melodia*) were the most abundant birds observed during winter 1992 (Tables 13 and 14). Wading birds were observed on ponded water provided by beaver (*Castor canadensis*) activity and borrow pits. Raptors observed included the red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), and northern harrier (*Circus cyaneus*).

In spite of 500 trap nights conducted during the 1991 summer, few small mammals were captured. One year later, an increase in the number of small mammals captured was observed. The most abundant species included the cotton rat (*Sigmodon hispidus*), eastern harvest mouse (*Reithrodontomys humilus*), cotton mouse (*Peromyscus gossypinus*), and rice rat (*Orzomys palustris*) (Table 15). Medium-sized mammals surveyed by the use of scent stations included the eastern cottontail (*Sylvilagus floridanus*) and nine-banded armadillo (*Dasypus novemcinctus*). Large mammals observed included the coyote (*Canis latrans*) and white-tailed deer (*Odocoileus virginianus*).

As might be expected, the vegetation and wildlife observed at Lake George immediately following tree planting is characteristic of early successional communities. The study conducted by Morgan (1993) invites many questions regarding habitat restoration in the Mississippi Delta and the monitoring of bottomland hardwood restoration projects. Early successional habitat is scarce in the Mississippi Delta (Morgan et al. 1995). The land is either under agricultural production or supports small, fragmented bottomland hardwood forests (Delta National Forest, Yazoo National Wildlife Refuge, and Panther Swamp National Wildlife Refuge are notable exceptions). The mitigation of Corps flood-control projects, the NRCS Wetlands Reserve Program, initiatives by the U.S. Fish and Wildlife Service, the Nature Conservancy, and Ducks Unlimited are supporting the reforestation of thousands of hectares of frequently flooded agricultural fields within the Mississippi Delta. Restoration planners should consider maintaining some acreage in early stages of succession.

The objective of the Lake George project was to restore wildlife habitat for species that require mature bottomland hardwood forests. However, significant mast production from the planted oak seedlings will not occur for at least 20 years. Vertical structure and canopy cover of the planted forest may only slightly resemble the lost forest after 50 years. Restoration of soil processes may require even longer. For Lake George, determining restoration success would be meaningful only after the planted bottomland hardwood forest had the potential to support the target animal species. The high cost makes long-term monitoring commitments unrealistic. The observance of key plant and animal species during the pioneer or subclimax successional stages may indicate that the planted bottomland hardwood forest is proceeding successfully towards the desired functioning habitat.

3 Other Important Studies

Preliminary results from two long-term studies supported by the WRP were initiated at Lake George. These are described and discussed in the following sections.

Mixed-Species Plantings

The forestry profession has been criticized for planting monoculture forests. Biodiversity can be enhanced by establishing mixed-species plantations. A study by Carlson and Goeltz[1] investigates the effects of mixed-species plantings on bottomland hardwood seedling survival, growth, and form. The study is located west of the west-side levee. In January 1992, 1-year-old bare-root water oak, Nuttall oak, and green ash (*Fraxinus pennsylvanica* var. *subintegerrima*) were each planted on a Dundee and Sharkey soil at either 6-ft or 9-ft spacings. Mixing the species was facilitated by establishing the plantations in a triangular arrangement. Each species dominated one corner of the triangle with their number decreasing approaching the opposite triangle face. A replant of mortality was accomplished in January 1993, using 2-year-old seedlings of each species. Disking and herbicide applications were used to control herbaceous and woody plant competition.

Canopy closure will be required before the effects of the interactions between species on survival, growth, and form can be studied. However, the observations of early survival verify that bare-root plantings can be successful at locations that flood infrequently (Table 16). As in the study by Williams et al. (1992), poorer survival was observed for water oak, regardless of where the seedlings were planted.

Nuttall Oak Clipping Study

The study by Morgan (1993) mentioned the severe vegetation competition for planted seedlings at Lake George (Table 8). Several herbicides appear effective for

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[1] D. W. Carlson and J. C. G. Goeltz. (1994). "Lake George mixed-species hardwood plantation study," Unpublished progress report to U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

postplanting weed control, but application rates and placement must be carefully monitored to prevent seedling injury or mortality (Miller 1992). Also, the cost of herbicide applications can be prohibitive (i.e., $100/ha for banded application).[1] Bush-hogging may be a more cost-effective option ($40/ha). However, little is known about what effect the accidental cutting of the seedlings would have on survival and growth. Janzen and Hodges (1987) observed higher growth rates and improved form of oak natural regeneration clipped at the soil surface following the removal of midstory and understory competition. A study currently underway by Young and Williams is observing the survival and growth of Nuttall oak seedlings either clipped immediately after planting or bush-hogged during the second growing season.

One-year-old bare-root Nuttall oak seedlings were hand-planted in March 1993 on a Sharkey soil located west of the west-side levee at Lake George. Seedlings were either clipped to the groundline following planting, bush-hogged in spring 1994, or remained uncut.

Survival was high regardless of whether the seedlings were clipped following planting or bush-hogged at the beginning of the second growing season (Table 17). Clipped seedlings were 20 cm shorter than the uncut seedlings after the second growing season. These preliminary results suggest that bush-hogging may be an inexpensive means of controlling vegetation competition without causing increased seedling mortality due to accidental cutting. Inferences regarding the effects of clipping or bush-hogging on long-term height growth would be premature. Again, because of the study location, frequent flooding does not appear to be a problem. Complete inundation of cut seedlings may decrease survival. The interactions between flooding stress, weed control, and seedling damage due to herbicides or cutting should be studied.

[1] Personal Communication, Texas Forest Service, 1993.

4 Conclusion

The Lake George project provided an excellent opportunity to conduct applied research regarding the bottomland hardwood reforestation of frequently flooded agricultural fields. Lake George research indicated that planting bare-root seedlings on sites that flood infrequently can be a successful means of establishing a bottomland hardwood forest. Direct seeding may also be successful on the drier sites, but less so than planting seedlings. Planting container seedlings may provide an answer to the poor survival observed for bare-root seedlings or direct seeding on flood-prone sites. Following planting, the Lake George sites quickly provided valuable pioneer successional stage habitat for vegetation and animal species. The studies point to the importance of planning prior to implementing a restoration project. A thorough knowledge of the BLHW restoration site, especially site hydrology, and the flood tolerance of the endemic tree species will aid in meeting project objectives. Literature is available to help in the overall planning of a BLHW restoration project (Allen and Kennedy 1989, Kusler and Kentula 1990; Hammer 1992; Allen 1993; Davis 1993). The additional guidance provided by the current research on bottomland hardwood reforestation will support the numerous restoration projects planned for the Mississippi Delta.

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Table 1
Relative Flood Tolerance of Selected Bottomland Hardwood Tree Species Planted on Restoration Sites

Common Name	Scientific Name	Flood Tolerance[1]
Green ash	*Fraxinus pennsylvanica*	Moderate
River birch	*Betula nigra*	Moderate
Eastern cottonwood	*Populus deltoides*	Moderate to weak
Baldcypress	*Taxodium distichium*	Tolerant
Water elm	*Planera aquatica*	Tolerant
Sweet gum	*Liquidambar styraciflua*	Moderate
Black tupelo	*Nyssa sylvatica* var. *sylvatica*	Weak
Water tupelo	*Nyssa aquatica*	Tolerant
Sugarberry	*Celtis laevigata*	Moderate
Water hickory	*Carya aquatica*	Moderate
Shellbark hickory	*Carya laciniosa*	Weak
Red maple	*Acer rubrum*	Moderate
Cherrybark oak	*Quercus pagodafolia*	Weak to intolerant
Laurel oak	*Quercus laurifolia*	Moderate to weak
Live oak	*Quercus virginiana*	Weak to intolerant
Nuttall oak	*Quercus nuttallii*	Moderate
Overcup oak	*Quercus lyrata*	Moderate
Pin oak	*Quercus palustris*	Moderate
Shumard oak	*Quercus shumardii*	Weak
Swamp chestnut oak	*Quercus michauxii*	Weak
Water oak	*Quercus nigra*	Weat to moderate
Willow oak	*Quercus phellos*	Weak to moderate
Persimmon	*Diospyros virginiana*	Moderate
American sycamore	*Platanus occidentalis*	Moderate
Black willow	*Salix nigra*	Tolerant
Yellow poplar	*Liriodendron tulipifera*	Intolerant

Note: Adapted from McKnight et al. (1981).

[1] Tolerant = Species able to survive and grow on sites in which soil is saturated or flooded for long, indefinite periods during the growing season; Moderate = Species able to survive and grow on sites in which soil is saturated or flooded for several months during the growing season, but high mortality can be expected if flooding persists or reoccurs consecutively for several years; Weak = Species able to survive and grow on sites in which soil is saturated or flooded for relatively short periods during the growing season; Intolerant = Species that are not able to survive even short periods of soil saturation or flooding.

Table 2
Gravimetric Soil Moisture Content Within the Root Zone Measured During the 1992 Growing Season for the East Side (Williams et al. 1992) and West Side (Miwa 1993) Studies Conducted at Lake George in Matching Tree Species to Site Conditions

	Percent Soil Moisture					
	Dundee Soil		Forestdale Soil		Sharkey Soil	
Date[1]	East	West	East	West	East	West
Mar 21	24	28	39	33	NA[2]	82
Apr 04	22	26	38	31	39	52
May 02	22	24	37	28	40	38
May 18	19	15	35	20	34	29
May 30	23	21	36	23	33	34
Jun 13	21	25	37	28	NA[2]	42
Jul 10	14	22	28	26	31	38
Jul 23	25	2,125	34	24	38	37
Sep 07	23	26	36	29	33	40

[1] Date represents sampling time for west-side study. East-side study samples were taken within 4 days of west side study samples.
[2] NA = Data not available.

Table 3
First-Year Survival and Growth of Four Bottomland Oak Species in Lower Mississippi Valley Alluvial Soils

	Planted Seedlings		Acorn Germinants		
Species	Survival, %	Height Growth, cm	Survival, %	Height, cm	Diameter Growth,[1] cm
Cherrybark oak	82 a[2]	9.7 b	45 b[3]	8.7 c[3]	0.18 c
Nuttall oak	84 a	19.0 a	72 a[3]	17.0 a	0.36 a
Shumard oak	71 a	9.2 b	73 a	10.5 b	0.24 b
Water oak	78 a	17.8 a	66 a	7.9 c[3]	0.16 c

Note: Values are means of spilt-split plots.
[1] Groundline diameter.
[2] Means followed by the same letter within a column are not significantly different at the 0.05 level.
[3] Significant difference at the 0.05 level between planting methods.

Table 4
First-Year Height Growth and Survival of Three Bottomland Hardwoods Species on Three Alluvial Soils at Lake George in 1992

Soil Type	Species	Height, cm	Survival, percent
Dundee	Cherrybark oak	-2	91
	Nuttall oak	-2	99
	Water oak	-12	65
Forestdale	Cherrybark oak	-31	53
	Nuttall oak	-2	97
	Water oak	-23	57
Sharkey	Cherrybark oak	-26	50
	Nuttall oak	-5	94
	Water oak	-13	71

Table 5
Seedling Biomass Data for 1-0 Bare-Root and Container Seedlings for Each Planting Date

Planting Date	Height, cm		Diameter, mm		Root Biomass, g		Shoot Biomass, g		Root to Shoot Ratio	
	BR	CO	BR	CO	BR	CO	BR	CO	BR	CO
Jan	62.9 a	47.1 b	7.4 a	6.1 a	6.72 a	4.46 a	9.24 a	4.93 b	0.75 a	0.92 b
Feb	52.0 a	46.1 b	7.0 a	6.6 a	5.87 a	4.14 a	5.44 a	6.11 a	1.11 a	0.72 b
Mar	53.0 a	39.0 b	6.3 a	5.5 a	5.08 a	3.26 b	5.72 a	3.50 b	0.90 a	0.98 a
Jun	56.1 a	53.9 a	7.3 a	.5 a	5.26 a	3.24 b	6.47 a	5.01 b	0.84 a	0.67 b

Note: BR = 1-0 bare root; CO = Container; Means with the same letter in rows are not significantly different at 0.05 level.

Table 6
Meteorological Data Comparing 30-year Average (1961-1990) to the 1993 Growing Season

Sampling Dates	% Soil Moisture	30-Year Average Precipitation, cm	1993 Precipitation, cm	30-Year Average Temperature, °C		1993 Temperature, °C	
				Max	Min	Max	Min
Jan 22	36.3	14.02	10.24	12.3	1.23	13.1	3.9
Feb 16	36.2	13.63	12.09	15.1	3.1	14.8	2.8
Mar 11	43.7	16.20	11.48	20.0	7.6	17.1	6.7
Jun 08	26.7	9.04	8.17	32.7	20.4	32.4	21.8
Jul 08	25.2	8.05	9.29	33.7	21.6	34.4	23.5
Jul 13	37.5						
Sept 10	28.7	8.28	2.89	30.7	20.2	31.3	18.3
Sept 22	25.0						

Table 7
Seedling Height Growth and Survival for the Three Stock Types at the End of the 1993 Growing Season

Planting Date	Seedling Growth			% Seedling Survival		
	1-0 Bare Root	Container	Direct Seeded	1-0 Bare Root	Container	Direct Seeded
Jan	-14.16	3.36	0	57	80	49
Feb	-11.46	3.67	0	58	84	34
Mar	-29.00	-2.06	0	25	83	24
Jun	-39.44	-4.26	0	5	83	9

Table 8
Plant Species Occurring at the Lake George Restoration Project Site During Summer 1991, Spring 1992, and Summer 1992

Species	Summer 1991	Spring 1992	July 1992
Acalypha virginica	X	X	X
Ambrosia artemisifolia	X		X
Ammania coccineum			X
Apocynum spp.	X		X
Aster spp.		X	X
Aster simplex	X		X
Brunnichia cirrhosa	X	X	X
Campsis radicans	X	X	X
Cardiospermum halicacabum	X		
Cephalanthus occidentalis	X	X	X
Croton capitatus		X	X
Convolvulus sepium	X		X
Cyperus spp.	X	X	X
Cyperus strigosis	X		X
Datura strammonium	X	X	X
Digitaria spp.	X	X	X
Diodea teres		X	X
Echinocloa crusgalli	X	X	X
Euphorbia spp.	X	X	X
Fraxinus pennsylvanica	X	X	
Helinium amarum	X	X	X
Ipomoea spp.	X	X	X
Lamium amplexicaule	X		X
Lepidium virginicum	X	X	
Liquidambar styraciflua	X	X	X
Ludwigia alternifolia	X		
Paspalum spp.	X	X	X
Passiflora incarnata	X	X	X
Penthorum sedoides			X
Platanus occidentalis	X	X	X
Poa spp.	X	X	X

(Continued)

Table 8 (Concluded)			
Species	**Summer 1991**	**Spring 1992**	**July 1992**
Polygonum hydropiperoides	X		
Polygonum spp.	X	X	X
Quercus phellos	X	X	X
Rubus hispidus	X		X
Rubus spp.	X	X	X
Rumex verticillatus	X	X	X
Rumex obtusifolius	X	X	X
Trifolium incarnatum		X	X
Salix nigra	X	X	X
Sesbania macrocarpa	X	X	X
Setaria faberii			X
Sicyos angulatus	X		
Solanum carolinense	X	X	X
Solidago spp.	X	X	X
Sonchas arvensis	X	X	X
Sorghum halepense	X	X	X
Vernonia altissima	X	X	X
Vicia angularis	X	X	
Xanthium strumarium	X	X	X
Total species present	41	39	41

Table 9
Mean Percent Canopy Cover of Individual Dominant Species by Plant Community at the Lake George Restoration Project Site During Summer 1991

Plant Community	Species	Percent Canopy Cover[1]
Ridge top	*Sorghum halepense*	47
	Ipomoea spp.	45
	Xanthium strumarium	31
	Paspalum spp.	18
	Acalypha virginica	11
Slope	*Ipomoea spp.*	41
	Campsis radicans	38
	Sesbania macrocarpa	27
	Paspalum spp.	16
	Sorghum halepense	15
Swale	*Ipomoea spp.*	58
	Xanthium strumarium	28
	Campsis radicans	27
	Brunnichia cirrhosa	23
	Sesbania macrocarpa	22

[1] Because of physical overlap of individual plants, percentages of dominant species listed exceed 100 percent.

Table 10
Mean Percent Cover of Individual Dominant Species by Plant Community at the Lake George Restoration Project Site During Summer 1992

Plant Community	Species	Percent Canopy Cover[1]
Ridge top	*Campsis radicans*	31[1]
	Aster spp.	30
	Sorghum halepense	23
	Solidago spp.	15
	Ipomoea spp.	14
Slope	*Aster spp.*	47
	Campsis radicans	43
	Brunnichia cirrhosa	18
	Ipomoea spp.	18
Swale	*Campsis radicans*	65
	Brunnichia cirrhosa	30
	Ipomoea spp.	19
	Aster spp.	12

[1] Because of physical overlap of individual plants, percentages of dominant species listed exceeded 100 percent.

Table 11
Avian Species Present by Plant Community at the Lake George Restoration Project Site During Summer 1991

Common Name[1]	Ridge Top	Slope	Swale
Barn Swallow	X	X	X
Barred Owl			X
Brown Thrasher		X	
Cattle Egret[2]	X	X	X
Northern Bobwhite	X	X	
Common Yellowthroat	X		X
Dickcissel[2]	X	X	X
Eastern Meadowlark	X	X	X
Great Blue Heron	X		X
Great Egret			X
Great Horned Owl			X
Indigo Bunting			X
Killdeer			X
Little Blue Heron			X
Mourning Dove	X	X	
Northern Cardinal	X	X	X
Prothonotary Warbler			X
Red-winged Blackbird[2]	X	X	X
Ruby-throated Hummingbird	X	X	
Wood Duck			X
Yellow-billed Cuckoo			X
Total species present	11	10	17

[1] Ornithological common names are accepted as standards by avian taxonomists.
[2] Dominant species on area.

Table 12
Mean Densities of Selected Dominant Species by Plant Communities at the Lake George Restoration Project Site During Summer 1991

Species	Plant Community	Density/Ha
Red-winged Blackbird	Ridge top	16.5a
	Slope	8.3a
	Swale	7.3a
Dickcissel	Ridge top	5.7a
	Slope	3.9ab
	Swale	1.8b
Cattle Egret	Ridge top	0.06a
	Slope	0.21b
	Swale	3.60b
Mourning Dove	Ridge top	1.10a
	Slope	0.81a
	Swale	0.00b

Note: a, ab, b = significant differences ($p<0.05$).

Table 13
Avian Species Present by Plant Community at the Lake George Restoration Project Site During February 1992

Common Name[1]	Ridge Top	Slope	Swale
American Woodcock	X	X	X
Chipping Sparrow	X	X	
Common Snipe			X
Dickcissel	X		X
Eastern Meadowlark		X	
Killdeer	X		
Loggerhead Shrike	X		
Mallard			X
Northern Harrier	X	X	X
Red-tailed Hawk	X		X
Red-winged Blackbird[2]	X	X	X
Savannah Sparrow[2]	X	X	X
Song Sparrow[2]	X	X	X
Swamp Sparrow[2]	X	X	X
White-throated Sparrow	X	X	
White-crowned Sparrow	X		
Total species present	13	9	10

[1] Common names are standards accepted by avian taxonomists.
[2] Dominant species.

Table 14
Mean Densities of Dominant Avian Species by Plant Communities at the Lake George Restoration Project Site During February 1992

Species	Plant Community	Density/Ha
Red-winged Blackbird	Ridge top	4.4a
	Slope	9.6a
	Swale	15.7a
Song Sparrow	Ridge top	11.4a
	Slope	11.6a
	Swale	3.0b
Swamp Sparrow	Ridge top	6.2a
	Slope	3.8ab
	Swale	0.6b
Savannah Sparrow	Ridge top	1.4ab
	Slope	2.9a
	Swale	0.3b

Note: a, ab, b = significant differences ($p<0.05$).

Table 15
Mammals Present at the Lake George Restoration Project Site in June 1991 Through September 1992, and the Method by Which They Were Identified

Species	Trapped	Scent Station	Observed
Armadillo		X	X
Beaver			X
Bobcat		X	
Cotton Mouse	X		
Coyote		X	X
Eastern Harvest Mouse	X		X
Grey and Red Foxes		X	
Hispid Cotton Rat	X		X
House Mouse	X		
Mink			X
Norway Rat	X		
Opossum		X	
Raccoon		X	
Rice Rat	X	X	
Striped and Spotted Skunks		X	
Fox and Grey Squirrels		X	
White-footed Mouse	X		
White-tailed Deer			X
Total species observed	7	9	7

Table 16
Total Percentage of Living Trees on Each Area for 1992 and 1993

Species	Dundee				Sharkey				Average	
	6 × 6		9 × 9		6 × 6		9 × 9			
	'92	'93	'92	'93	'92	'93	'92	'93	'92	'93
Green ash	87.3	99.6	80.6	99.2	99.8	93.2	93.2	99.9	86.1	99.6
Nuttall oak	91.9	92.3	93.1	94.1	90.5	92.3	83.1	88.4	89.7	91.7
Water oak	60.8	69.3	59.8	69.7	83.5	99.8	30.0	44.6	51.7	62.8

Table 17
Seedling Height Growth and Survival of Clipping

Treatment	1993 Height, cm	1994 Height, cm	1993 Survival	1994 Survival
1-0 Bare-root	41.6	91.9 a	92	88
Clipped	28.2	71.1	97	94
Bush-hogged	42.8	37.6	92	80

a = significant at the 1 percent level of probability.

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13. ABSTRACT *(Maximum 200 words)*

In the Mississippi Delta, initiatives by Federal, State and private agencies will attempt to restore unproductive, frequently flooded agricultural fields back to bottomland hardwood wetlands. However, early reforestation efforts by direct seeding or planting bare-root seedlings have been only marginally successful. Prolonged flooding and poor seedling quality are two reasons for the low seedling survival. Bottomland hardwood restoration planners need guidance on applied issues such as species selection, stock type selection, planting schedules, and site monitoring.

The objective of the Lake George Bottomland Hardwood Wildlife and Wetland Restoration Project is to restore functioning bottomland hardwood wetland habitat by reforesting 3,600 ha of agricultural fields located in the Mississippi Delta. The Lake George Project provided an opportunity to conduct applied research on several bottomland hardwood reforestation topics. University and Federal agency scientists conducted studies on matching tree species to the site, selecting plant stock type, selecting when to plant, and monitoring early habitat development following planting.

Lake George research indicated that planting bare-root seedlings on sites that flood infrequently can be a successful means of establishing a bottomland hardwood forest. Direct seeding may also be successful on the drier sites, but less so than planting seedlings. Planting container seedlings may provide an answer to the poor survival observed for bare-root seedlings or direct seeding on flood-prone sites. Following planting, the Lake George sites quickly provide valuable pioneer successional stage habitat for vegetation and animal species.

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