BOTTOMLAND HARDWOOD ESTABLISHMENT AND AVIAN COLONIZATION OF REFORESTED SITES IN THE MISSISSIPPI ALLUVIAL VALLEY

R. RANDY WILSON [1,2], USGS-Patuxent Wildlife Research Center, 2524 South Frontage Road, Suite C, Vicksburg, MS 39180, USA

DANIEL J. TWEDT, USGS-Patuxent Wildlife Research Center, 2524 South Frontage Road, Suite C, Vicksburg, MS 39180, USA

Abstract: Reforestation of bottomland hardwood sites in the Mississippi Alluvial Valley has markedly increased in recent years, primarily due to financial incentive programs such as the Wetland Reserve Program, Partners for Wildlife Program, and state and private conservation programs. An avian conservation plan for the Mississippi Alluvial Valley proposes returning a substantial area of cropland to forested wetlands. Understanding how birds colonize reforested sites is important to assess the effectiveness of avian conservation. We evaluated establishment of woody species and assessed bird colonization on 89 reforested sites. These reforested sites were primarily planted with heavy-seeded oaks (*Quercus* spp.) and pecans (*Carya illinoensis*). Natural invasion of light-seeded species was expected to diversify these forests for wildlife and sustainable timber harvest. Planted tree species averaged 397 ± 36 stems/ha^{-1}, whereas naturally invading trees averaged 1675 ± 241 stems/ha. However, naturally invading trees were shorter than planted trees and most natural invasion occurred <100 m from an existing forested edge. Even so, planted trees were relatively slow to develop vertical structure, especially when compared with tree species planted and managed for pulpwood production. Slow development of vertical structure resulted in grassland bird species, particularly dickcissel (*Spiza americana*) and red-winged blackbird (*Agelaius phoeniceus*), being the dominant avian colonizers for the first 7 years post-planting. High priority bird species (as defined by Partners in Flight), such as prothonotary warbler (*Protonotaria citrea*) and wood thrush (*Hylocichla mustelina*), were not frequently detected until stands were ≥15 years old. Canonical correspondence analysis revealed tree height had the greatest influence on the bird communities colonizing reforested sites. Because colonization by forest birds is dependent on tree height, we recommend inclusion of at least one fast-growing tree species (e.g., cottonwood [*Populus deltoides*], or sycamore [*Platanus occidentalis*]) in the planting stock to encourage rapid avian colonization.

Key Words: avian colonization, bottomland hardwood forest, Mississippi Alluvial Valley, reforestation, tree establishment

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In the Mississippi Alluvial Valley, only 24% (2.6 million ha) of the once nearly contiguous bottomland hardwood forest remains in a highly fragmented landscape (Rudis 1995, Twedt and Loesch 1999). Altered hydrology and past management have degraded many of the existing forest fragments (Gosselink and Lee 1989). As a result of bottomland hardwood forest loss, populations of many avian species have declined. These declines are not only due to loss of habitat (Brown and Twedt In press) but also to the adverse effects of forest fragmentation (Robinson et al. 1995). As a result, few of the remaining forest fragments are large enough to support targeted population objectives of high priority birds such as cerulean warblers (*Dendroica cerulea*) and Swainson's warblers (*Limnothlypis swainsonii*; Mueller et al. 2000). To ameliorate this lack of habitat, Partners in Flight drafted a habitat conservation plan for the Mississippi Alluvial Valley (Twedt et al. 1998) with initiatives that propose returning a substantial area of cropland to forested wetlands. This reforestation should improve landscape metrics (e.g., core-area, connectivity) and ultimately increase populations of forest birds (Mueller 1996).

Several programs (e.g., Farm Bill, Water Resources Development Act, North American Waterfowl Management Plan) have increased public awareness of ecological and economic issues in the Mississippi Alluvial Valley and provided a means to reforest marginal agricultural land. As such, reforestation of bottomland hardwood forests in the Mississippi Alluvial Valley has been undertaken through government initiated conservation programs such as the Wetland Reserve Program (U.S. Department of Agriculture), Partners for Wildlife Program (U.S. Fish and Wildlife Service), and through the efforts of state and private conservation agencies. Historically, reforestation efforts have emphasized planting heavy-seeded oaks and pecans due to: (1) their limited dispersal capabilities; (2) their importance to wildlife species (e.g., mast crops); and (3) their high timber value (Allen and Kennedy 1989). Light-seeded species were assumed to establish naturally

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[1] E-mail: randy_wilson@fws.gov

[2] Current address: Lower Mississippi Valley Joint Venture, U. S. Fish and Wildlife Service, 2524 South Frontage Road, Suite B, Vicksburg, MS 39180, USA

Table 1. Area and species planted on 89 reforested bottomland sites in the Mississippi Alluvial Valley. Actual area reforested was 3,174 ha; because multiple species were planted within most reforested sites, reported area and number of sites exceed actual values.

Species	Scientific name	Ha[a]	Sites[b]
Water oak	*Quercus nigra*	2,958	76
Nuttall oak	*Q. nuttallii*	2,879	76
Willow oak	*Q. phellos*	2,550	60
Cherrybark oak	*Q. pagoda*	1,091	29
Sweet pecan	*Carya illinoensis*	1,056	24
Persimmon	*Diospyros virginiana*	732	12
Green ash	*Fraxinus pennsylvanica*	297	6
Shumard oak	*Q. shumardii*	270	5
Sugarberry	*Celtis laevigata*	257	5
Bald cypress	*Taxodium distichum*	201	5
Pin oak	*Q. palustris*	160	5
Overcup oak	*Q. lyrata*	270	4
Sawtooth oak	*Q. acutissima*	233	4
Swamp chestnut oak	*Q. michauxii*	119	4
White oak	*Q. alba*	308	3
Sweetgum	*Liquidambar styraciflua*	115	3
Red mulberry	*Morus rubra*	98	2
Black gum	*Nyssa sylvatica*	81	2
Oak (species unknown)	*Q.* species.	43	2
Black cherry	*Prunus serotina*	64	1
Live oak	*Q. virginiana*	64	1
Post oak	*Q. stellata*	64	1
American elm	*Ulmus americana*	64	1
Cedar elm	*U. crassifolia*	64	1

[a] Total area on which species was planted
[b] Number of sites on which the species was planted

in the "oak" plantations and result in a diverse forest. However, it is unclear if this approach has been successful at meeting the stated objectives of: (1) creating diverse forested habitat for migratory songbirds, waterfowl, game and non-game species; (2) creating habitat for endangered species; and (3) maintaining a sustainable timber harvest (Strader et al. 1994).

As restored bottomland hardwood sites will likely have ephemeral habitat qualities and species compositions at different seral stages, their contribution to specific conservation goals is likely dynamic. Therefore, assessing the contribution of reforestation to avian conservation will include monitoring the extent of reforestation to evaluate its influence on landscape metrics (Twedt and Uihlein, 2005) and monitoring avian use of reforested sites. Although the extent of reforestation is being documented through a reforestation database at the Lower Mississippi Valley Joint Venture (Blaine Elliott, pers. comm.), no long-term monitoring program has been established to evaluate woody species establishment or colonization by wildlife species on these reforested sites. As a first step toward assessing successional changes on reforested sites, we used a chrono-sequence approach to assess avian colonization and woody species establishment on reforested sites of different ages within the Mississippi Alluvial Valley.

METHODS

We randomly selected 89 reforested sites in 4 states (Tennessee [*n* = 3], Arkansas [*n* = 17], Mississippi [*n* = 47], and Louisiana [*n* = 22]), from databases maintained by the USGS Patuxent Wildlife Research Center, the Lower Mississippi Valley Joint Venture, and Yazoo National Wildlife Refuge Complex. We visited selected sites between 1 April and 9 July 1998 to assess their breeding bird and woody species populations. Between sunrise and noon, we identified and enumerated all birds along two 200 m wide parallel transects. Transects originated at the edge of the reforested site that was nearest mature forest. All birds heard or seen within 100 m of the transect centerline were recorded, although flyovers were not recorded. Optimally, transects were ≥200 m apart and 500 m long. These survey parameters required that reforested sites were >30 ha. However, many sites were <30 ha or had dimensions (e.g., sites <500 m in length) that resulted in variation in the number and length of transects. Therefore, we expressed survey results as densities (birds/100 ha) to standardize among reforested sites. To increase the likelihood of including only breeding birds in our surveys we visited southern locations in early spring, whereas more northern locations were visited later. Even so, 7 species were encountered outside of their normal breeding range (Price et al. 1995); these migrant species were not included in our subsequent analyses.

To assess invasion of woody species, we followed the same transect lines established for bird surveys. Along each transect line, we obtained vegetation measurements within 0.002-ha (2.5 m radius) circular plots at distances of 10, 20, 30, 40, 50, 75, and 100 m, and at 50 m intervals thereafter, to 500 m. At each point, we identified, enumerated, and measured the height of all trees and shrubs (but not vines) ≥0.5 m in height. If forest edges other than the point of origin were more proximate to the sampling location, the distance from the sampling location to nearest forested edge was estimated and recorded.

From land managers, we obtained data on the species planted at each reforested site. Within each site, we categorized each tree encountered as planted if it was of the same species as was planted on the site. All species not planted on the site were considered natural invaders. However, all trees <2 m tall on sites >20 years post-planting were considered natural invaders. Canonical correspondence analysis (ter Braak 1986) was used to

Figure 1. Mean (± SE) number of woody species (excluding vines) encountered within 0.002 ha circular plots on reforested bottomlands within the Mississippi Alluvial Valley during 1998. Number above error bars is the number of sites within each age class (n). The number of plots surveyed varied among sites (28 ± 0.5: range 14-46), but we found no relationship between species richness and intensity of surveys ($r^2 = 0.02$, $P = 0.17$).

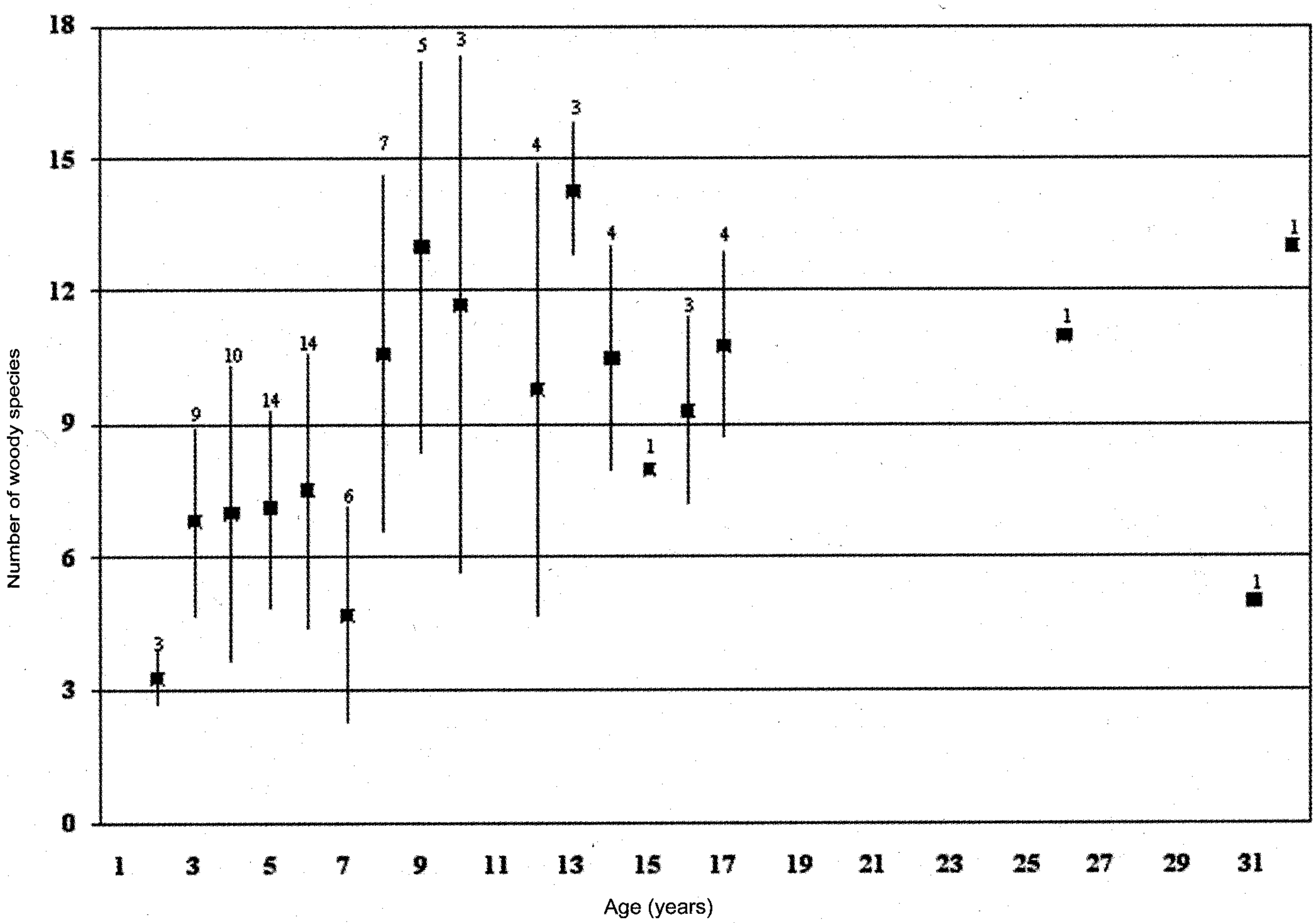
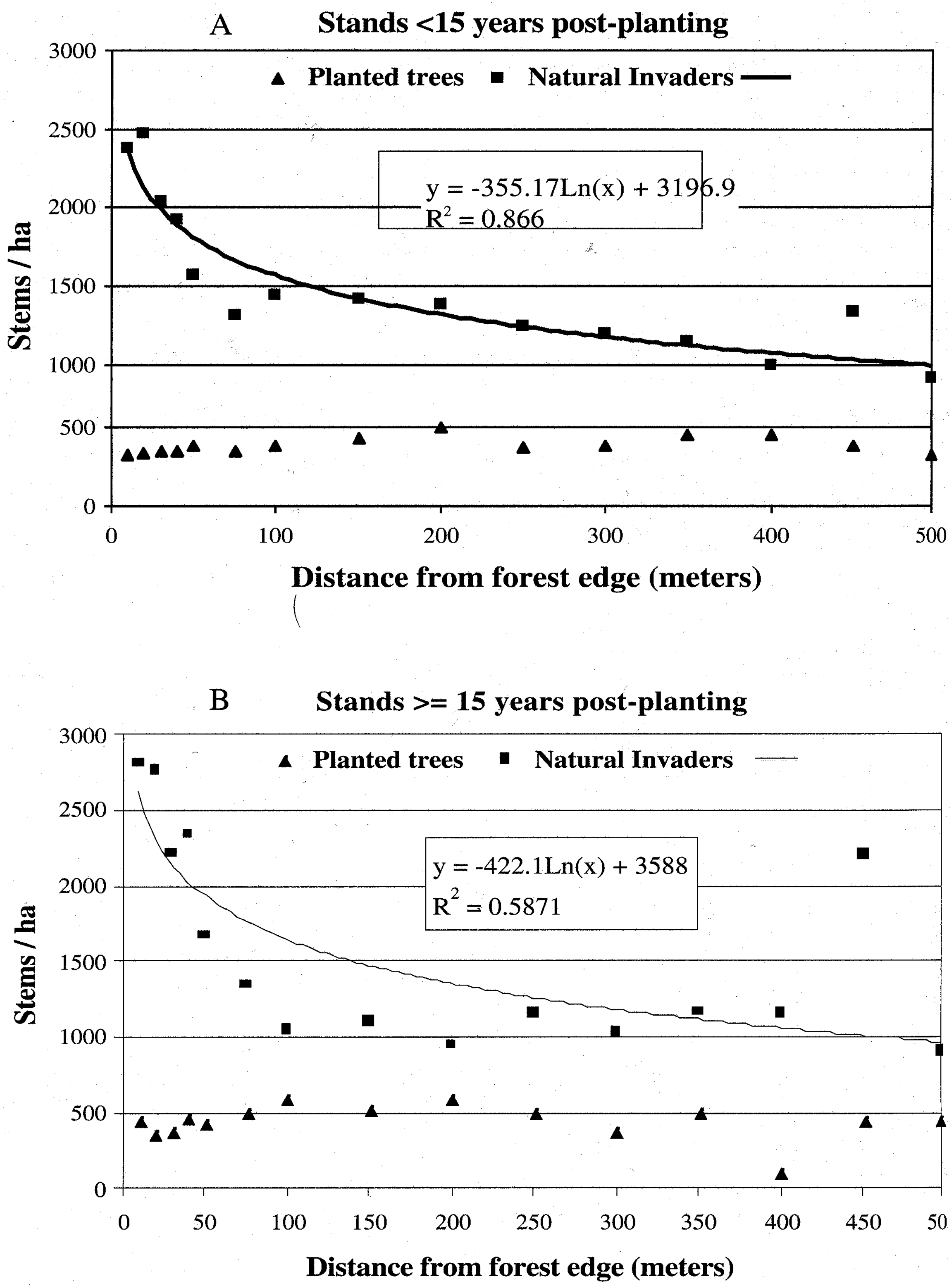


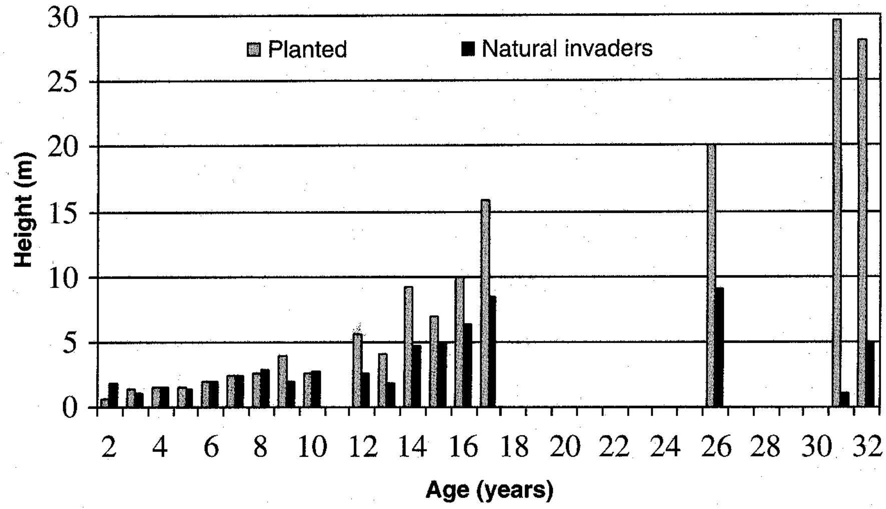
Figure 2. Mean density of woody species (excluding vines) on reforested bottomlands within the Mississippi Alluvial Valley during 1998 as a function of the distance from nearest forest edge for stands <15 years of age (A) and >15 years of age (B)



relate densities of avian species to habitat variables.

Based on changes in vegetation structure, we grouped reforested sites into 3 stages: (1) grassland (≤7 years old); (2) shrub-scrub (from 8 to 14 years old); and (3) maturing forest (≥15 years old). We used indicator species analysis (Dufréne and Legendre 1997) to assess the affinity of avian species for each seral stage of reforest development.

Figure 3. Mean height of planted and naturally invading woody species (excluding vines) on reforested bottomlands within the Mississippi Alluvial Valley during 1998 in relation to the number of years post-planting.



RESULTS

Woody Vegetation

Reforested sites ranged in age from 2 to 32 years post-planting. Average area of reforested sites was 36 ± 4 ha (mean ± SE). Although 24 species were reported planted on reforested sites (Table 1), the vast majority of trees planted were Nuttall oak (*Quercus nuttallii*), water oak (*Q. nigra*), and willow oak (*Q. phellos*); these species were planted on ≥60 sites. Cherrybark oak (*Q. pagoda*) and sweet pecan were planted on >20 sites, and persimmon (*Diospyros virginiana*) was planted on 12 sites. The remaining 18 species were planted on ≤6 sites, with 6 of these species planted on a single site.

We detected an average of 8.5 ± 0.4 woody species (trees and shrubs) on reforested sites but the number of species per site ranged from 2 to 18. Four species (Nuttall oak, water oak, green ash [*Fraxinus pennsylvanica*], and sweetgum [*Liquidambar styraciflua*]) were detected on >10% of vegetation survey plots. These 4 species, along with boxelder (*Acer negundo*), which we found on 7% of vegetation plots, accounted for 60% of all trees on reforested sites. However, the number of woody species we detected increased significantly on older sites ($r^2 = 0.13$, $P < 0.01$, Fig. 1). Because the number of vegetation plots varied slightly among study sites (due to different transect distances), our estimates of species richness may be biased (i.e., species richness is known to increase as the area surveyed increases). Even so, unequal sampling effort did not contribute to the increase in species richness that we observed; we actually surveyed fewer vegetation plots on older reforested sites ($r^2 = 0.04$, $P = 0.05$). Furthermore, we detected no relationship between the number of vegetation plots surveyed and species richness ($r^2 = 0.02$, $P = 0.17$).

Density of planted trees averaged 397 ± 36 (mean ± SE; $n = 89$) stems/ha^{-1}. On the other hand, natural invaders averaged 1,676 ± 241 stems/ha^{-1}, far exceeding densities of planted species. However, mean density of natural invaders was inflated by very high numbers of invaders on a few sites (maximum = 14,285 stems·ha^{-1}); the median number of natural invaders was only 806 stems/ha^{1}. Examination of stem density in relation to distance from seed sources (i.e., mature trees adjacent to reforested sites) showed a significant decline in density of naturally invading species with distance from forest edge ($P < 0.01$). Conversely, density of planted species did not vary with distance from forested edge ($P = 0.75$). Examination of mean stem densities across all reforested sites revealed highest densities of invading species were within 100 m of a forest edge, particularly during the early years (<15 years post-planting) of stand development (Fig. 2, A). However, even after 15 years of stand development, the tendency toward greater stem density of natural invaders near forested edges remained (Fig. 2, B)

When compared with hardwood plantations managed for pulpwood (Twedt and Portwood 1997), reforested "oak" sites were slow to develop vertical structure (Fig. 3). Seventy-five percent of planted trees were <2 m tall until 7 years post-planting. During the next 7 years, 75% of planted trees remained <6 m tall, and only at ≥15 years post-planting did the heights of 75% of the planted trees exceed 7 m. Even with the relatively slow vertical

Table 2. Avian species and mean (±SE) densities•100 ha detected on reforested bottomland sites 2 to 32 years post-planting in the Mississippi Alluvial Valley during 1996.

Common name	Species Code	Scientific name	2 - 7 years (*n* = 52)	8 - 14 years (*n* = 26)	15 - 32 years (*n* = 11)
Wood duck	WODU	*Aix sponsa*	0.96 ± 0.96	0	0
Mallard	MALL	*Anas platyrhynchos*	0.19 ± 0.19	0.38 ± 0.38	0
Red-shouldered hawk	RSHA	*Buteo lineatus*	0	0	0.53 ± 0.53
Northern bobwhite	NOBO	*Colinus virginianus*	2.83 ± 0.84	0.38 ± 0.38	0
Mourning dove	MODO	*Zenaida macroura*	2.30 ± 1.11	3.86 ± 1.52	6.47 ± 4.00
Yellow-billed cuckoo	YBCU	*Coccyzus americanus*	0.50 ± 0.40	1.65 ± 0.75	12.64 ± 3.71
Ruby-throated hummingbird	RTHU	*Archilochus colubris*	0.79 ± 0.40	3.35 ± 1.43	0.53 ± 0.53
Red-bellied woodpecker	RBWO	*Melanerpes carolinus*	0	0.19 ± 0.19	2.27 ± 2.27
Downy woodpecker	DOWO	*Picoides pubescens*	0.10 ± 0.10	0	5.98 ± 3.27
Pileated woodpecker	PIWO	*Dryocupus pileatus*	0	0	0
Eastern wood-pewee	EAWP	*Contopus virens*	0	0.30 ± 0.30	1.81 ± 1.81
Acadian flycatcher	ACFL	*Empidonax virescens*	0	0	17.06 ± 16.31
Great crested flycatcher	GCFL	*Myiarchus crinitus*	0.78 ± 0.48	0.30 ± 0.30	0.91 ± 0.91
Eastern kingbird	EAKI	*Tyrannus tyrannus*	0.19 ± 0.19	0.98 ± 0.76	0
White-eyed vireo	WEVI	*Vireo griseus*	0.87 ± 0.37	14.61 ± 3.49	11.05 ± 4.97
Bell's vireo	BEVI	*Vireo bellii*	0.12 ± 0.12	0	0
Yellow-throated vireo	YTVI	*Vireo flavifrons*	0	0	1.81 ± 1.81
Red-eyed vireo	REVI	*Vireo olivaceus*	0	0.57 ± 0.57	3.67 ± 2.53
Blue jay	BLJA	*Cyanocitta cristata*	0	1.15 ± 0.85	12.56 ± 4.01
American crow	AMCR	*Corvus brachyrhynchos*	0	0	2.80 ± 2.80
Carolina chickadee	CACH	*Poecile carolinensis*	0	2.99 ± 1.33	20.92 ± 5.39
Tufted titmouse	TUTI	*Baeolophus bicolor*	0	0.85 ± 0.49	11.27 ± 4.44
Carolina wren	CARW	*Thryothorus ludovicianus*	0.46 ± 0.33	5.03 ± 1.51	21.98 ± 5.64
Blue-gray gnatcatcher	BGGN	*Polioptila caerulea*	0	1.50 ± 0.63	3.14 ± 1.90
Wood thrush	WOTH	*Hylocichla mustelina*	0	0.87 ± 0.69	9.02 ± 3.84
Gray catbird	GRCA	*Dumetella carolinensis*	0	1.92 ± 0.86	0
Northern mockingbird	NOMO	*Mimus polyglottos*	1.05 ± 0.52	0	0
Brown thrasher	BRTH	*Toxostoma rufum*	0.10 ± 0.10	0	0
Northern parula	NOPA	*Parula americana*	0	0.30 ± 0.30	0.45 ± 0.45

Table 2, cont'd.

Common name	Species Code	Scientific name	2 - 7 years (n = 52)	8 - 14 years (n = 26)	15 - 32 years (n = 11)
Prairie warbler	PRAW	*Dendroica discolor*	0.38 ± 0.38	0	0
Prothonotary warbler	PROW	*Protonotaria citrea*	0	0.62 ± 0.44	4.79 ± 2.20
Swainson's warbler	SWWA	*Limnothlypis swainsonii*	0	0	0.45 ± 0.45
Kentucky warbler	KEWA	*Oporornis formosus*	0	0	3.18 ± 2.16
Common yellowthroat	COYE	*Geothlypis trichas*	9.72 ± 1.24	19.56 ± 2.61	4.68 ± 2.84
Hooded warbler	HOWA	*Wilsonia citrina*	0	0	0.45 ± 0.45
Yellow-breasted chat	YBCH	*Icteria virens*	7.13 ± 1.68	52.17 ± 7.23	32.92 ± 10.09
Summer tanager	SUTA	*Piranga rubra*	0.10 ± 0.10	0.76 ± 0.44	3.92 ± 1.93
Eastern towhee	EATO	*Pipilo erythrophthalmus*	0.36 ± 0.28	5.78 ± 1.83	15.05 ± 3.83
Northern cardinal	NOCA	*Cardinalis cardinalis*	3.02 ± 0.84	25.08 ± 5.18	65.09 ± 9.85
Blue grosbeak	BLGR	*Guiraca caerulea*	0	0.53 ± 0.38	0
Indigo bunting	INBU	*Passerina cyanea*	16.90 ± 3.23	46.32 ± 5.91	34.72 ± 8.71
Dickcissel	DICK	*Spiza americana*	102.03 ± 8.78	43.76 ± 12.68	1.95 ± 1.95
Red-winged blackbird	RWBL	*Agelaius phoeniceus*	150.05 ± 20.13	80.89 ± 22.70	10.64 ± 4.84
Eastern meadowlark	EAME	*Sturnella magna*	9.26 ± 1.84	0.96 ± 0.48	0
Common grackle	COGR	*Quiscalus quiscula*	3.27 ± 1.12	6.41 ± 6.41	1.81 ± 1.81
Brown-headed cowbird	BHCO	*Molothrus ater*	0.83 ± 0.38	8.41 ± 2.73	8.93 ± 2.90
Orchard oriole	OROR	*Icterus spurius*	2.68 ± 0.79	11.20 ± 3.12	3.70 ± 2.24
American goldfinch	AMGO	*Carduelis tristis*	0.12 ± 0.12	0	0

development of planted species, their heights were markedly greater than those of naturally invading woody species (Fig. 3). Indeed, 75% of the invading trees were <3 m tall until 14 years post-planting and 75% of invading trees remained <9 m tall regardless of plantation age.

Avian Colonization

We detected 48 species of birds that were potential breeding species on these reforested sites (Table 2). The first axis resulting from canonical correspondence analysis (Fig. 4) explained 21.3% of the variability in our bird density data and was highly correlated with maximum height of woody vegetation (r = 0.96). Forest birds were associated with tall woody plants, whereas grassland birds were associated with short woody plants. Age of reforestation was positively correlated with maximum tree height (r = 0.86). The second and third canonical correspondence analysis axes explained only 5.7 and 5.1% of the remaining variability in these data. Although the variability along the second canonical axis was not adequately explained by our vegetation parameters, the variability along the third canonical axis (Fig. 4) was correlated with density of woody species (r = 0.78) and woody species richness (r = 0.76). Clearly, avian colonization on these reforested sites was dictated by height of the trees and because of the similarity of woody species composition among sites, avian colonization was indirectly affected by stand age.

When we grouped reforested sites into grassland (≤7 years old), shrub-scrub (8-14 years old), and maturing forest (≥15 years old) stages, indicator species analysis found 20 of the 48 bird species were significantly ($P \leq 0.01$) associated with one of these 3 groups (Fig. 4). Three avian species (dickcissel, eastern meadowlark

[*Sturnella magna*], and red-winged blackbird) were indicative of the grassland stage of reforestation. Six species (common yellowthroat [*Geothlypis trichas*], gray catbird [*Dumetella carolinensis*], indigo bunting [*Passerina cyanea*], orchard oriole [*Icterus spurious*], white-eyed vireo [*Vireo griseus*], and yellow-breasted chat [*Icteria virens*]) were indicative of the shrub-scrub stage of reforestation. Finally, 11 species, including such high priority species as wood thrush and prothonotary warbler, characterized the bird community in maturing forests (Fig. 4).

DISCUSSION

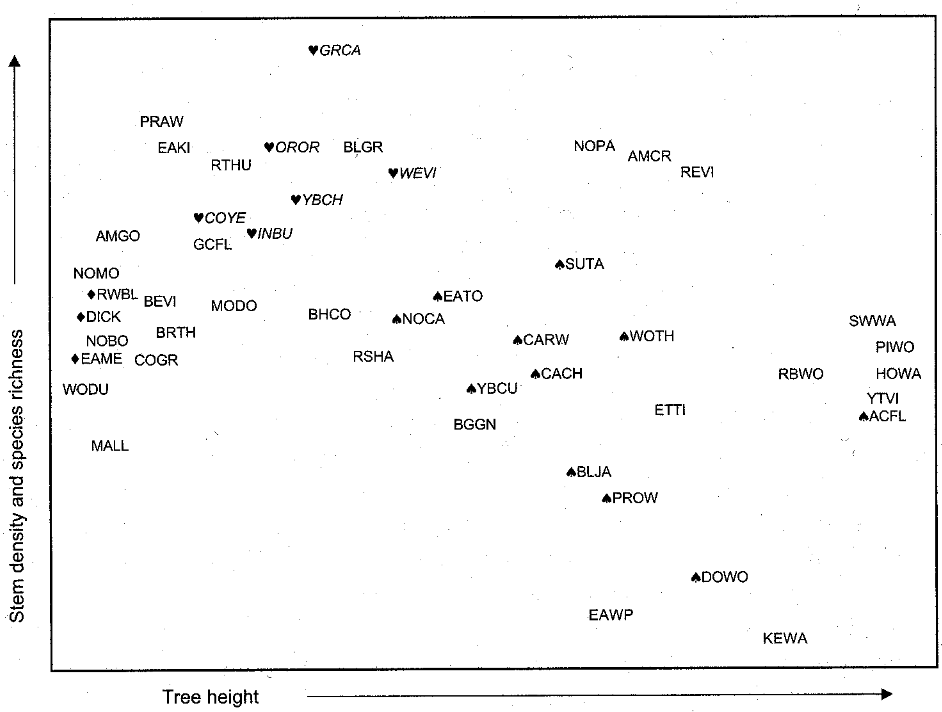
Tree Establishment

Bottomland hardwood reforestation within the Mississippi Alluvial Valley has typically taken an extensive rather than an intensive approach. That is, efforts have been focused on methods that allow large areas to be planted with minimum funding. As a result, reforestation typically consisted of planting 3-5 heavy-seeded species with no weed control. Natural invasion of light-seeded species was assumed to be sufficient to establish a diverse forest (Haynes et al. 1995). The mix of species planted on reforested sites we surveyed was highly skewed toward 3 oak species (Nuttall, water and willow) with 2 additional species, cherrybark oak and sweet pecan, also planted on about a third of these sites. This homogeneity of plantings is similar to that reported by King and Keeland (1999) where oaks, pecans, and baldcypress comprised 87% of all trees planted in the Mississippi Valley.

These methods appear adequate for establishment of heavy-seeded species (Allen 1990), but the amount of natural invasion by light-seeded species varies greatly among reforested sites (Haynes and Moore 1988). Our finding of the 2,072 ± 250 stems/ha^{-1} far exceeded the stated goal of 500 stems/ha^{-1} (Strader et al. 1994). However, very high densities of naturally invading trees on some sites inflated the overall mean stem density; the median stem density was only 1,170 stems/ha^{-1}. Even so, this was more than double the target density. However, our findings were in agreement with other studies (Allen 1997, Allen et al. 1998) in that density of naturally invading woody species declined significantly with distance from a forested edge. Hence, fields that were not close to existing forests may have suffered from lack of propagules and therefore had limited natural woody invasion. This may account for 25% of our study sites having <300 stems/ha^{-1} of naturally invading woody species. Land managers should consider the juxtaposition of potential reforestation sites in the landscape, and when sites are far from potential seed sources additional woody species, including light-seeded species, should be planted.

Because reforested sites initially lacked canopy cover, these sites maintained a high percentage of ground cover (>90%) that likely inhibited growth of developing trees through competition for light, water, and nutrients. As a result of competition, as well as herbivory, the oaks planted on our study sites were relatively slow to develop vertical

Figure 4. Distribution of avian species (4 letter codes referenced in Table 2) that were detected on reforested bottomland sites in the Mississippi Alluvial Valley along the first (horizontal) and third (vertical) canonical correspondence analysis axes. Species with diamonds are indicative of stands ≤7 years old, species with hearts are indicative of stands between 8 and 14 years old, and species with spades are indicative of stands ≥15 years old (P ≤ 0.01, Dufréne and Legendre 1997)



structure, when compared to the rapid development of cottonwood planted in plantations where herbaceous competition is reduced during the first year of development (Twedt and Portwood 1997). In this study, planted species showed relatively little increased height until 7-10 years after planting. Richness of woody species also began to increase at about 7 years post-planting.

Even though natural invaders outnumbered planted species, they were significantly shorter than planted species. Thus, despite the numbers of natural invaders, their relegation to sub-dominance within the forest canopy resulted in older reforested sites retaining the visual perception of "oak" plantation monocultures. We believe that silvicultural manipulation (e.g., thinning) of these maturing forests (>15 years post-planting) will promote increased diversity of co-dominant trees within these reforested stands.

Avian Colonization

Our results are consistent with the scant data available for avian colonization of various bottomland hardwood successional stages; species richness increased with age of successional stage due to an increase in structural complexity (Buffington et al. 1997, Nuttle 1997).

For the first 7 years post-planting, reforested sites supported avian communities typical of grasslands; primarily dickcissels and red-winged blackbirds. Although reforested sites in the Mississippi Alluvial Valley will eventually provide mature forest habitat, the extended period in which they retain grassland-like conditions provides suitable habitat for grassland birds. Although most birds breeding in grasslands within these bottomland sites are not of high management concern, several species of management concern, including high densities of raptors, use these young reforested sites during winter (Hamel et al. 2001).

Concurrent with the emergence of woody stems above herbaceous ground cover, the avian community shifted toward species typical of scrub-shrub habitat. Indigo bunting, yellow-breasted chat, and orchard oriole were among the characteristic birds on reforested sites from 8 to 14 years post-planting. After age 15, crown development increased and canopies began to close. At this time, the avian community began to resemble a forest bird community with species such as Carolina chickadee (*Poecile carolinensis*), tufted titmouse (*Baeolophus bicolor*), and yellow-billed cuckoo (*Coccyzus americanus*) appearing.

In contrast, Twedt and Portwood (1997) reported that forest birds such as yellow-billed cuckoo, Acadian flycatcher (*Empidonax virescens*), and Baltimore oriole (*Icterus galbula*) held breeding territories in 5 to 7-year-old cottonwood plantations. Likewise, Twedt et al. (2002) found greater species richness and more avian territories in 2 to 9-year-old cottonwood plantations than in 4 to 10-year-old oak plantings and concluded that cottonwood plantations provided greater avian conservation value than did oak plantings of similar age. These findings support our conclusion that vertical structure is of paramount importance for colonization by forest bird species.

Although initial colonization on these sites was dependent on vertical development of trees, on sites >20 years old, avian richness and abundance appeared to be influenced by forest structure (heterogeneity within sites). For example, a 32 year-old stand that had multiple small openings (the result of tree mortality) that resembled tree fall gaps had increased heterogeneity of forest structure and consequently greater avian richness. Thinning maturing forests (>15 years old) would likely increase the heterogeneity of forest structure and would likely result in a more diverse and numerous bird community.

MANAGEMENT IMPLICATIONS

As conservation plans for forest songbirds in the Mississippi Alluvial Valley promote reforestation of cleared habitats, it is important that we understand how birds respond to reforestation practices. Under the historical practice of planting almost exclusively oaks and pecans, colonization by forest bird species may require ≥15 years for forest generalists and longer for forest specialists. Therefore, we recommend inclusion of at least 1 fast-growing tree species (e.g., cottonwood, sycamore, black locust [*Robinia psuedoacacia*]) and 1 understory/fleshy fruit species (e.g., hawthorn [*Crataegus* spp.], mulberry [*Morus* spp.], dogwood [*Cornus* spp.] in the planting stock. Due to greater natural invasion of woody plants close to existing forests, fast-growing and fleshy fruited trees should be planted >100 m from a forest edge to ensure establishment throughout the field. We recommend weed control for the first year after planting to enhance survival and vertical development of planted species.

On reforested sites with high survival rates (i.e., dense stocking rates) we recommend post-planting management (e.g., thinning) as these stands mature to increase within-stand heterogeneity of vegetation structure. Because many reforested sites lack sufficient area to support an economical timber harvest, an alternative approach would be to girdle trees or to inject selected trees with herbicide. This approach should create light gaps for development of understory vegetation and concurrently provide suitable substrates for cavity-dependent species; a missing component of many reforested sites.

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