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Short communication

Effects of restoration techniques on breeding birds in a thermally-impacted bottomland hardwood forest

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Abstract

We evaluated the effects of revegetation techniques on breeding bird communities in a bottomland hardwood forest impacted by thermal effluent. In 1993, sections of the Pen Branch bottomland on the Savannah River Site, South Carolina, were herbicide-treated (glyphosate), burned, and planted; other sections were planted only while others were unaltered and served as controls. Few differences in the avian community occurred at 1 and 2 years post-treatment among treatments. Plots that were herbicide-treated, burned, and planted had greater species richness in 1994 and abundance in 1995 than sections that were planted only ($P < 0.05$). Bird species composition differed slightly among treatments and White-eyed Vireos (*Vireo griseus*), Common Yellowthroats (*Geothlypis trichas*), Indigo Buntings (*Passerina cyanea*), and Red-winged Blackbirds (*Agelaius phoeniceus*) were the most abundant species in the corridor. Revegetation techniques used to restore this thermally-impacted bottomland had little effect on the avian communities 1 and 2 years post-treatment. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Avian communities; Bottomland; Restoration; Thermal effluent

1. Introduction

Land use practices in riparian habitats can induce large-scale vegetation changes. Channelization, cattle grazing, waste-water discharge, timber harvest, and thermal discharge impact riparian vegetation and alter plant succession. On the Savannah River Site (SRS), SC, USA, the original bottomland hardwood forest of the Pen Branch corridor and delta was eliminated by thermal

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discharge (Sharitz et al., 1974). Recovery of vegetative communities proceeds slowly in forested wetlands damaged by thermal stress (Dunn and Sharitz, 1987). Attempts have been made to increase the rate of succession and thus recovery of riparian forests (Nix and Cox, 1987; Chambers and Henckel, 1989). However, results have been inconsistent and the process is slow and expensive (McKelvin, 1992). Nevertheless, revegetation of damaged bottomlands can improve habitat for a wide range of wildlife.

Late-successional bottomland hardwood forests are important to many species of birds, especially neotropical migrants and forest interior species (Harris, 1989). Bird density and diversity are correlated positively with structural heterogeneity in riparian habitats (Swift et al., 1984) and species diversity generally is highest in late-successional habitats (Johnston and Odum, 1956; Lanyon, 1981) such as mature bottomland forests (Zimmerman and Tatschl, 197.5; Dickson, 1978). We evaluated the impacts of various revegetation techniques on the breeding bird communities associated with a bottomland hardwood forest deforested by thermal effluent.

2. Study site

This study was conducted on the US Department of Energy's SRS. This 78 OOO-ha facility is located in Aiken, Allendale, and Barnwell Counties, SC, USA. The principal forested habitats of SRS are pine (*Pinus* spp.) stands of various ages in the uplands and bottomland hardwoods associated with the numerous creeks that traverse the site. Several bottomlands received thermal discharge from nuclear reactors from the mid-1950s until the late 1980s. In 1954, Pen Branch began receiving regular influxes of thermal effluent from the SRS's K reactor (water temperatures > 45°C, high water levels, and increased sedimentation). Thermal input ceased in 1988 but high flow rates continued until August 1993. Before 1951, Pen Branch was characterized as a closed canopy forest of bald cypress *(Tuxodiurn distichum*) and water tupelo (*Nyssa aquatica*) along with other bottomland hardwood species located in more well-drained areas (Sharitz et al., 1974). The corridor currently is characterized by a dense black willow (*Salix nigra)* and smooth alder (*Alnus serrulata*) thicket interspersed with grassy openings.

Study plots were established in the Pen Branch corridor, which ranges in width from 100 to 300 m. The corridor was divided into upper and lower sections (Fig. 1) based on the hydrology of the creek (Duloherry et al., 1995). In the upper section, three control and three treatment plots alternated along the length of the corridor. Treatment plots received an aerial application of Rodeo™ (glyphosate) at a rate of 5.8 1 ha $^{-1}$ in September 1993 and were burned in late November 1993. From 27 December 1993 to 4 January 1994, these treatment plots were planted with swamp chestnut oak *(Quercus michauxii*), cherrybark oak (*Q. falcata* var. *pagodaefolia*), water oak *(Q. nigra),* water hickory (*Carya aquatica*), persimmon *(Diospyros virginianu),* green ash (*Fraxinus pennsylanica),* swamp tupelo *(N. sylvatica* var. *biflora*), water tupelo and bald cypress seedlings. Additional seedlings were planted in the winter of 1994-95 and included cherrybark oak, water oak, water hickory, water tupelo, green ash, shumard oak (Q. *shumardii*), sycamore (*Platanus occidentalis*), and pignut hickory (C. *glubra).* Control plots were unaltered.

In the lower section, control and treatment plots (*n* = 3) alternated along the length of the corridor. These lower treatment plots were planted in February 1993 with seedlings of swamp chestnut oak, cherrybark oak, water hickory, water tupelo, green ash and bald cypress. An enrichment planting using the same species was conducted in winter 1994-95, except swamp tupelo replaced swamp chestnut oak. Control plots were unaltered. Plantings were spaced 3.66 x 3.66 m (~ 748 trees ha $^{-1}$).

3. Methods

Five times per year from mid-May to late June in 1994 and 1995, we conducted an avian census along the creek. We used the fixed-radius (50 m) point count method (Hutto et al., 1986; Ralph et al., 1993) to estimate bird abundance, species richness, and species diversity in treatment and control plots. Each of the 12 plots contained one census point located in the plot center. The census points were marked with conduit pipe. Censusing began at sunrise and was completed within 3.5 h. Ail visual and auditory detections of birds, except those flying over the site, were recorded for a period of 5 min from the plot center (Ralph et al., 1993). Species detected within ± 3 min of each point count period while en route to census points and species detected outside the census plot were recorded for inclusion in the species list.

Abundance is reported as mean number of birds detected per treatment. Species richness is mean number of species encountered per treatment. Bird species diversity, reported as mean diversity per treatment, was computed using the Shannon-Weaver formula (Shannon and Weaver, 1949). We used one-way analysis of variance to compare mean bird abundance, species richness, and diversity among treatments and controls for each year and Tukey's test to compare means for differences ($\alpha = 0.05$). Comparisons within species among treatments were made if sample sizes were large ($n \geq 30$).

We estimated percent green ground cover, percent water cover, shrub density, canopy height, percent canopy closure, and basal area in treat-

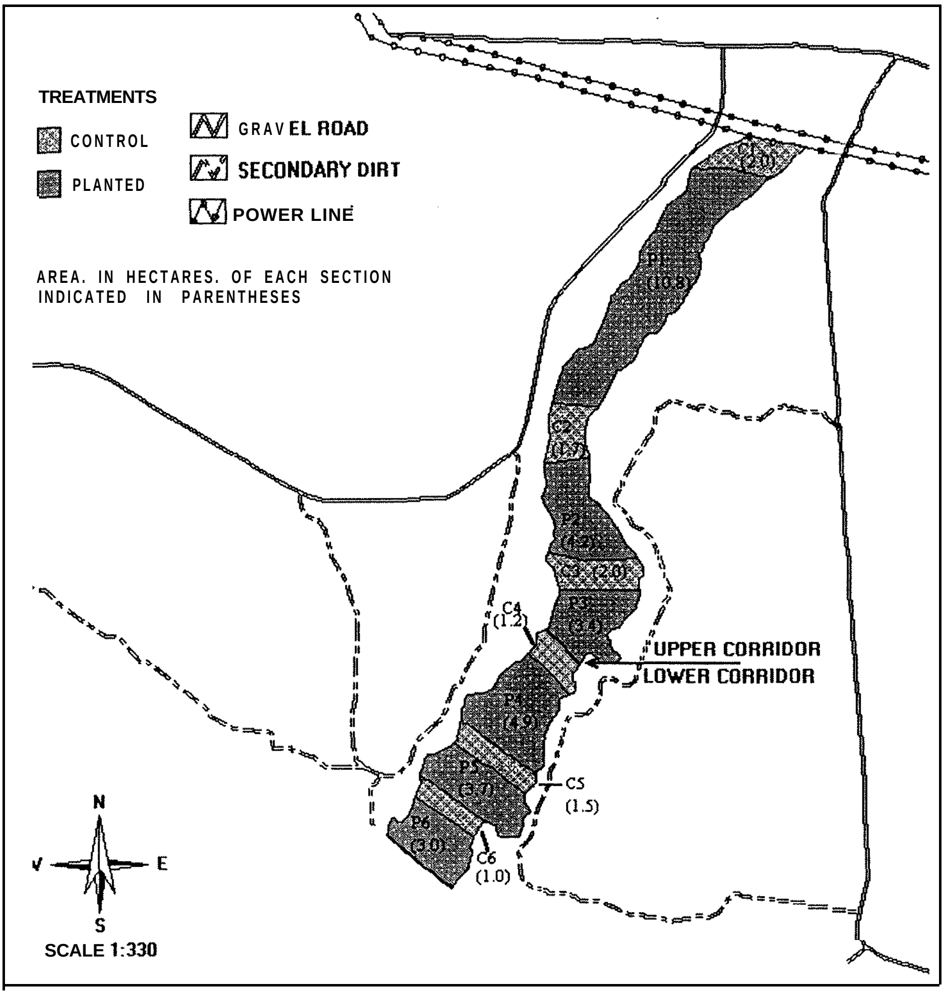

Fig. 1. Map of revegetation treatments in the Pen Branch corridor, Savannah River Site, SC, 1994–95

Table 1
Pearson correlation coefficients of habitat characteristics and estimated avian community parameters of Pen Branch, Savannah River Site, SC, USA, 1994-95

Habitat characteristic	Abundance		Richness	
	r	*P* values	*r*	*P* values
Ground cover	0.06	0.84	0.45	0.14
Water cover	-0.33	0.29	-0.52	0.08
Shrubs per ha	-0.14	0.66	-0.49	0.11
Canopy height	-0.47	0.12	-0.57	0.05
Canopy closure	-0.70	0.01	-0.81	0.001
Basal area	-0.48	0.12	-0.13	0.68
Vegetation profile (m)				
0.0–0.5	-0.36	0.26	0.24	0.46
0.5–1.0	-0.35	0.26	0.29	0.35
1.0–1.5	-0.23	0.47	0.28	0.37
1.5–2.0	-0.43	0.17	0.19	0.56
2.0-2.5	-0.34	0.28	0.18	0.58
2.5-3.0	-0.32	0.32	0.10	0.75

ment and control plots using the methods of James and Shugart (1970). Vegetative profile was estimated using a 3-m density board (Nudds, 1977; Noon, 1981) marked in 0.5-m intervals. A total of 24 habitat plots, two per census point, were sampled. Estimates of avian community parameters were correlated with habitat measurements using Pearson's correlation coefficient.

4. Results

The vegetation of the upper treatments different from the rest of the corridor. Most of the willow and alder in the upper treatments were dead except along the edge of the waterways. Most of the dead vegetation remained standing and dominated these treatment areas. The only other vegetation that was alive in the upper treatments were a few large trees, new herbaceous growth, including fireweed *(Erechtites hieracifolia)* and grasses, and some hardwood plantings which were l-2 m tall. There was no canopy in these areas. The vegetation in the upper controls and all of the lower section remained a willow/alder thicket. Mean canopy height in these areas was 8.0 m. There were frequent grassy openings throughout the corridor, particularly in the lower section. The hardwood plantings in the lower treatments were l-2 m tall, and contributed little to the vegetative structure. Few of the avian and habitat variables were correlated. Avian abundance and richness were correlated negatively with canopy closure, and richness was correlated negatively with canopy height (Table 1).

There were few differences in the avian communities among the four treatment groups (Table 2). In 1994, only species richness differed between upper treatments and lower treatments. Abundance was greater in the upper treatments than the upper controls and lower treatments in 1995. Although not significant in all cases, abundance, richness, and diversity values generally were greater in the upper treatments than the other plots 1 and 2 years post-treatment. None of the estimated avian parameters differed between the lower controls and treatments. In both years, the corridor was dominated by a few species: White-eyed Vireo *(Vireo griseus)*, Indigo Bunting *(Passerina cyanea),* Common Yellowthroat *(Geothlypis trichas)* and Red-winged Blackbird *(Agelaius phoeniceus).* These four species represented > 70% of all the birds detected each year. Northern Parula *(Parula americana)* and Blue-gray Gnatcatcher *(Polioptila caerulea)* also were common in the corridor.

There were some individual species differences among the various treatments, particularly among the four dominant species. Indigo Buntings were most common in the upper treatments in both years although only significantly in 1995 ($P < 0.05$). Although not significant, White-eyed Vireos were least common in the upper treatments in both years. Common Yellowthroats increased in abundance farther downstream, but there was not a significant difference in their abundance among treatments. Red-winged Blackbirds were exclusive to the lower control and treatment plots.

Hooded Warblers (*Wilsonia citrina*), observed on several occasions in both years, were found only in the upper control areas. Rufous-sided Towhee (*Pipilo erythrophthalmus*) were observed infrequently and only in upper treatment areas. Sample sizes of other species were too small to allow comparisons among treatments, although nearly all other species detected were found in more than one treatment type and were equally abundant among treatments in which they were detected.

5. Discussion

During the first 2 years post-treatment, there was little difference in the avian communities among the treatments. Although upper treatment plots were herbicide-treated, burned, and planted with hardwood seedlings, they still possessed vertical structure produced by numerous small snags. Dead woody vegetation, dense herbaceous growth, and some relatively large, scattered hardwoods, such as red maple (*Acer rubrum*) characterized these treatments. These dense brushy areas provided many singing perches and nesting sites. Indigo Buntings apparently preferred these sites over the control plots, unlike the White-eyed Vireos which were more common in the upper controls and the lower section. The greater abundance of Red-winged Blackbirds in the lower section versus the upper section likely reflects a gradual change in the vegetation downstream. The vegetation there was shorter and there were more frequent grassy openings closer to the delta of Pen Branch and the Savannah River. The lower treatment plots and all control plots were nearly indistinguishable because the planted seedlings in the lower treatments were ≤ 2 years old. Consequently, few differences in the avian community were observed among these areas. However, avian communities in the lower treatment plots may shift dramatically when the planted trees become dominant in the site. A greater change also is expected in the upper treatments as snags fall, dead vegetation decays, and seedlings grow.

Table 2
Mean abundance, species richness, and diversity of four treatment types in Pen Branch, Savannah River Site, SC, 1994-95

Site	Abundance			Richness			Diversity[a]		
	Mean	SE		Mean	SE		Mean	SE	
1994									
Upper control	17.2	2.0	A[b]	8.8	1.1	AR	1.78	0.12	A
Upper treatment	17.8	1.9	A	11.4	0.7	A	1.84	0.13	A
Lower control	14.4	1.5	A	8.6	0.8	AB	1.64	0.11	A
Lower treatment	17.0	1.0	A	7.4	0.7	B	1.57	0.01	A
1995									
Upper control	12.8	1.3	B	7.6	0.5	A	1.58	0.03	A
Upper treatment	18.4	1.3	A	8.0	0.5	A	1.69	0.11	A
Lower control	16.6	0.7	AB	8.4	0.7	A	1.65	0.06	A
Lower treatment	13.4	0.8	B	7.2	0.5	A	1.39	0.09	A

[a] Bird species diversity computed using $-\Sigma p_i \log_e p_i$.

[b] Means followed by the same letter. within the same column by year, are not significantly different at a = 0.05 (Tukey's studentized range test).

The Pen Branch corridor will continue to change as the vegetation changes. Censusing in later successional creeks elsewhere on SRS has provided an index of species expected to occur in Pen Branch over time (Buffington et al., 1997). Future censusing in Pen Branch will provide further insight into the effectiveness of the various treatments and will determine if the function of the corridor as wildlife habitat has been restored.

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